



EPA Region 5 Records Ctr.



361629

# REMEDIAL DESIGN WORK PLAN – APPENDIX A

## FIELD SAMPLING PLAN

HIMCO SITE  
ELKHART, INDIANA

Prepared For:  
Himco Site Trust

OCTOBER 2008  
REF. NO. 039611 (3)  
This report is printed on recycled paper.

**Prepared by:**  
**Conestoga-Rovers**  
**& Associates**

651 Colby Drive  
Waterloo, Ontario  
Canada N2V 1C2

Office: 519•884•0510  
Fax: 519•884•0525

## TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION.....	1
1.1 GENERAL.....	1
1.2 ASSOCIATED DOCUMENTS .....	1
1.3 BASIS .....	1
2.0 SAMPLING EQUIPMENT AND PROCEDURES.....	3
2.1 LANDFILL COVER.....	3
2.1.1 TOPOGRAPHIC SURVEY.....	3
2.1.2 SOIL SAMPLING.....	4
2.1.2.1 TEST TRENCHES .....	4
2.1.2.2 SOIL BORINGS .....	5
2.1.2.3 TEST PITS AND TEST PIT SAMPLING .....	6
2.2 LANDFILL GAS/SOIL GAS SAMPLING .....	8
2.2.1 GAS PROBE INSTALLATION .....	8
2.2.2 GAS PROBE SAMPLING .....	10
2.2.3 AMBIENT OUTDOOR AIR SAMPLING .....	12
2.3 GROUNDWATER INVESTIGATION AND MONITORING .....	12
2.3.1 VERTICAL AQUIFER SAMPLING.....	13
2.3.1.1 VERTICAL AQUIFER SAMPLING BY GEOPROBE.....	14
2.3.1.2 VERTICAL AQUIFER SAMPLING BY HOLLOW STEM AUGER.....	16
2.3.1.3 VERTICAL AQUIFER SAMPLING BY ROTOSONIC .....	17
2.3.2 MONITORING WELL INSTALLATION .....	19
2.3.2.1 SHALLOW AND INTERMEDIATE MONITORING WELL INSTALLATION .....	20
2.3.2.2 DEEP MONITORING WELL INSTALLATION.....	21
2.3.3 MONITORING WELL DEVELOPMENT.....	22
2.3.4 HYDRAULIC MONITORING .....	23
2.3.5 GROUNDWATER SAMPLING.....	24
2.3.6 MONITORING WELL ABANDONMENT .....	28
3.0 FIELD QUALITY CONTROL SAMPLING.....	30
3.1 GENERAL.....	30
3.2 FIELD DUPLICATE SAMPLES .....	30
3.3 EQUIPMENT BLANK SAMPLES .....	30
3.4 MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES.....	31
3.5 TRIP BLANK SAMPLES.....	31
4.0 SAMPLE CUSTODY AND DOCUMENT CONTROL.....	32
4.1 SAMPLE LABELING .....	32
4.2 FIELD CHAIN OF CUSTODY PROCEDURES .....	33
4.2.1 FIELD PROCEDURES.....	33

## TABLE OF CONTENTS

	<u>Page</u>
4.2.2	FIELD LOGBOOKS/DOCUMENTATION..... 33
4.2.3	TRANSFER OF CUSTODY AND SHIPMENT PROCEDURES ..... 35
4.3	LABORATORY CHAIN-OF-CUSTODY PROCEDURES ..... 36
4.4	LABORATORY STORAGE OF SAMPLES ..... 36
4.5	FINAL EVIDENCE FILES CUSTODY PROCEDURES ..... 36
5.0	FIELD CALIBRATION, PREVENTATIVE MAINTENANCE, AND STANDARD OPERATING PROCEDURES..... 38
5.1	PHOTOIONIZATION DETECTOR (PID)..... 38
5.2	FLAME IONIZATION/PID DUAL DETECTOR..... 38
5.3	PH, TEMPERATURE, ORP, AND CONDUCTIVITY INSTRUMENT..... 38
5.4	TURBIDITY INSTRUMENT ..... 39
5.5	DISSOLVED OXYGEN INSTRUMENT ..... 39
5.6	WATER LEVEL INDICATOR..... 39
5.7	LANDFILL GAS METER..... 39
5.8	DIGITAL MANOMETER ..... 40
6.0	EQUIPMENT CLEANING PROCEDURES..... 41
6.1	SAMPLING EQUIPMENT DECONTAMINATION PROCEDURES ..... 41
6.2	DRILLING EQUIPMENT DECONTAMINATION PROCEDURES ..... 41
7.0	MANAGEMENT OF INVESTIGATION-DERIVED WASTE (IDW) ..... 43
8.0	REFERENCES ..... 44

LIST OF FIGURES  
(Following Text)

FIGURE 2.1	PROPOSED TEST TRENCH LOCATIONS
FIGURE 2.2	COVER EVALUATION – PROPOSED SOIL SAMPLING LOCATIONS
FIGURE 2.3	PROPOSED TEST PIT LOCATIONS
FIGURE 2.4	PROPOSED SOIL GAS PROBE LAYOUT
FIGURE 2.5	TYPICAL SOIL GAS PROBE
FIGURE 2.6	TYPICAL SOIL GAS PROBE NEST
FIGURE 2.7	PROPOSED VERTICAL AQUIFER SAMPLING (VAS) LOCATIONS
FIGURE 2.8	TYPICAL OVERBURDEN MONITORING WELL
FIGURE 2.9	EXISTING MONITORING WELL AND STAFF GAUGE LOCATIONS
FIGURE 4.1	TYPICAL SAMPLE LABEL
FIGURE 4.2	TYPICAL COMPLETED CHAIN OF CUSTODY FORM

LIST OF TABLES  
(Following Text)

TABLE 2.1	SUMMARY OF SAMPLING AND ANALYSIS PROGRAM
TABLE 3.1	FIELD INSTRUMENT CALIBRATION AND QC SUMMARY
TABLE 4.1	CONTAINER, PRESERVATION, SHIPPING, AND PACKAGING REQUIREMENTS

## LIST OF ATTACHMENTS

ATTACHMENT A    STANDARD FORMS

ATTACHMENT B    FIELD STANDARD OPERATING PROCEDURES

ATTACHMENT C    ASTM METHODS

## LIST OF ACRONYMS

ARARs	Applicable or relevant and appropriate requirements
bgs	Below ground surface
CAEPA	California Environmental Protection Agency
CD	Consent Decree
CDA	Construction Debris Area
CIP	Community Involvement Plan
COC	Contaminant of Concern
CRA	Conestoga-Rovers & Associates
DO	Dissolved oxygen
e:Dat	Electronic data acquisition tool
FID/PID(s)	Flame ionization/photoionization dual detector
FSP	Field Sampling Plan
ft AMSL	Feet Above Mean Sea Level
ft bgs	below ground surface
ft/ft	Feet per foot
ft/day	Feet per day
ft/year	Feet per year
GCMS	Gas chromatograph mass spectrometer
GMP	Gas monitoring probe
HASP	Health and Safety Plan
HI	Hazard Index
HSA	Hollow stem auger
IDEM	Indiana Department of Environmental Management
IDW	Investigation derived waste
in.W.C.	Inches of water column
LEL	Lower explosive limit
LFG	Landfill gas
NAD	North American Datum
NMOCs	Non-methane organic compounds
NAVD	North American Vertical Datum
NPL	National Priority List
NTUs	Nephelometric turbidity units
MCL	Maximum contaminant level

## LIST OF ACRONYMS

mg/L	Milligrams per liter
mL/min	Milliliter per minute
mS/cm	MilliSiemen per centimeter
MS/MSD	Matrix spike/matrix spike duplicate
ORP	Oxidation-reduction reaction potential
PAHs	Polynuclear aromatic hydrocarbons
PID	Photoionization detector
PPE	Personal protective equipment
PRGs	Preliminary remediation goals
PSDs	Performing settling defendants
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RAO	Remedial action objectives
Redox	Oxidation-reduction potential
RD	Remedial Design
RD/RA	Remedial Design and Remedial Action
RD Work Plan	Remedial Design Work Plan
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SAP	Sampling and Analysis Plan
Site	Himco Site
SIM	Selected Ion Monitoring
SOPs	Standard Operating Procedures
SOW	Statement of Work
SSI/SCR	Supplemental Site Investigation/Site Characterization Report
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
U.S. DOL	United States Department of Labor
USCS	Unified Soil Classification System
VAS	Vertical Aquifer Sampling
VOCs	Volatile Organic Compounds

## 1.0 INTRODUCTION

### 1.1 GENERAL

This Field Sampling Plan (FSP) has been prepared in accordance with Section III of the Statement of Work (SOW) for the Remedial Design and Remedial Action (RD/RA) at the Himco Site (Site) in Elkhart, Indiana. Conestoga-Rovers & Associates (CRA) was retained by the Performing Settling Defendants (PSDs), collectively known as the Himco Site Trust, to prepare this FSP.

The purpose of this FSP is to outline the procedures to be used to perform the field activities in support of the Remedial Design Work Plan (RD Work Plan). The specific remedial design (RD) tasks are discussed in Section 3.0 and Section 4.0 of the RD Work Plan. This FSP, which is Appendix A to the RD Work Plan, and the Quality Assurance Project Plan (QAPP), which is Appendix B to the RD Work Plan, comprise the Sampling and Analysis Plan (SAP) for the RD.

### 1.2 ASSOCIATED DOCUMENTS

All activities discussed in this FSP will be performed in accordance with the QAPP and Health and Safety Plan (HASP) (Appendices B and C, respectively, of the RD Work Plan).

### 1.3 BASIS

This FSP defines and details the field sampling and data gathering activities required to collect the necessary data to complete the RD at the Site. Key components of the RD are as follows:

- landfill cover assessment and repair;
- landfill gas collection system;
- Site security, maintenance, and institutional controls;
- Construction Debris Area (CDA) remedy (excavation and removal of soil and debris or placement of soil cover over soil and debris);
- residential well abandonment and groundwater institutional controls;
- municipal water connections; and
- groundwater investigation and long-term monitoring.



Section III, Task 1 of the SOW requires the PSDs to complete pre-design studies to supplement the information collected during the Remedial Investigation and Feasibility Study (RI/FS) and subsequent investigations completed by the United States Environmental Protection Agency (USEPA) and the Indiana Department of Environmental Management (IDEM). A brief summary of the Site history and historical data is provided in Section 2.0 of the RD Work Plan. The scope of the Pre-Design Investigation is presented in Section 4.0 of the RD Work Plan and includes the following key components:

- boundary and topographic survey;
- landfill cover investigation, including shallow soil sampling and test trenching;
- test pitting and soil sampling in the CDA to confirm the presence and depth of waste;
- landfill gas and soil gas sampling on and off Site;
- investigation of groundwater quality east and southeast of the Site; and
- groundwater monitoring on and off Site.

## 2.0 SAMPLING EQUIPMENT AND PROCEDURES

The following sections are presented in the order in which they were presented in Section 4.0 of the RD Work Plan.

### 2.1 LANDFILL COVER

In order to determine the condition of the existing landfill cover, CRA will complete a pre-design survey. This study will include the following:

- perform a topographic survey of the existing landfill;
- advancement of shallow boreholes through the soil cover on a 100-foot grid;
- examination of collected soil samples to determine the thickness of the soil cover and waste at various points across the Site; and
- perform a physical inspection of the landfill to identify areas of settlement, erosion, poor vegetation (and possibly hydrogen sulfide gas accumulation, as evidenced by poor vegetative growth).

#### 2.1.1 TOPOGRAPHIC SURVEY

Survey data will be collected to complete topographic information in the area of the Site as bounded by northing N1534000 to the north, easting E405000 to the west, John Weaver Parkway (former Nappanee Street Extension) to the east, and County Road 10 to the south. The location of all boreholes, test pits, monitoring wells, gas probes, staff gauges, and fencelines will be determined and reported in Indiana State Plane Grid Coordinates. Elevations at 50-foot intervals will be surveyed relative to the 1983 North American Datum (NAD) for horizontal control and the North American Vertical Datum (NAVD) of 1988 for vertical control. Horizontal locations will be surveyed to the nearest 0.1-foot accuracy. Elevations for all monitoring well reference points (new and existing) will be surveyed to the nearest 0.01-foot accuracy. A topographic map with 2-foot contours will be produced for the new base map.

An on-Site assessment will be made to determine the extent of vegetation clearing required for a topographic survey. If required, clearing of vegetation will be performed minimizing disturbance of the landfill cover. Concurrent with the topographic survey, the surveyor will measure and stake in the field a 100-foot grid marked with 2-foot long wooden stakes. The grid will be used for soil sampling activities (see Section 2.1.2).

According to the Site information provided, the landfill is approximately 2,200 feet long and 1,400 feet wide, at its longest and widest points. Each wooden stake will be labeled alphanumerically by CRA according a column (alpha) and row (numeric) identifier (i.e., A1, A2, A3,...).

### 2.1.2 SOIL SAMPLING

Soil sampling activities performed at the Site will delineate the horizontal extent of the landfill, characterize the soil cover over the landfill, and delineate and characterize areas of construction debris not previously investigated.

The results of the soil sampling will be used to update the Site Plan with the current aerial extent of the landfill, assist in the development of a repair and maintenance plan of the landfill cover, provide additional characterization of the CDA.

The objective of the soil borings through the landfill cover and test pits in the CDA is to collect samples for visual characterization as well as chemical analyses. The objective of the test trenches at the landfill boundary is to collect samples for visual characterization only.

#### 2.1.2.1 TEST TRENCHES

Figure 2.1 presents the locations of proposed test trenches to be installed around the limit of the landfill, as discussed in Section 4.2 of the RD Work Plan. The test trenches are proposed at several locations to visually identify the type(s) of fill present and confirm the limits of the landfill. The 1996 landfill limit will be surveyed prior to test trenching activities.

An excavator or backhoe will be used to excavate each test trench. The test trench excavation procedures are as follows:

1. Each test trench will be assigned a unique identification number. Prior to starting the test trench excavations, the locations of each test trench will be staked in the field using the locations identified on Figure 2.1 and in the RD Work Plan.
2. The area immediately adjacent to the test trench will be used for stockpiling excavated waste and soil. Excavation spoils will be placed on polyethylene sheeting downwind of field personnel and in such a manner that any

water/runoff from the waste material will be directed back into the excavation. Soil/waste material that is temporarily stockpiled will be backfilled into the test trench before the contractor leaves the Site for the day.

3. Each test trench will be up to 30 feet long by approximately 3 feet wide and the outer limit of the trench, nearest the outer limit of the landfill, will extend to the bottom of fill or a maximum depth of 5 feet. The trenches will start from the landfill and move outwards until the horizontal limit of fill is confirmed. The lengths of individual test trenches will be determined in the field by the field representative based on conditions encountered during excavation.
4. If the horizontal limit of fill is not determined in any planned trench, trench lengths will be extended or a new trench will be excavated to attempt to locate the edge of fill. The nature and depth of fill material will be visually identified and recorded. This information will be used to define the lateral area of waste material to be covered.
5. A photographic log will be recorded of each test trench during its progression. The photographic record will list the date of each photograph, a specific description of what the photograph depicts, its location, and the photographer.
6. The dimensions of each excavation and a description of the soils encountered during excavation will be recorded on a Test Pit Stratigraphy Log, an example of which is provided in Attachment A.
7. Each test trench will be backfilled with the excavation materials in reverse order to that in which they were removed. Each test trench location will be restored to match surface conditions prior to excavation to the extent possible.

#### 2.1.2.2 SOIL BORINGS

Figure 2.2 presents the proposed shallow soil sampling locations that will be installed to determine the thickness and characteristics of the soil cover. As noted in Section 2.1.1, the surveyor will stake out a 100-foot grid across the Site. At each staked grid point, a borehole will be advanced using a direct push methodology (Geoprobe® or similar) to approximately 2 feet below ground surface (bgs). Soil samples will be collected with a disposable acetate sleeve.

All soil samples will be described using the Unified Soil Classification System (USCS) and United States Department of Agriculture textural chart and placed in a Ziploc® bag for headspace screening using a photoionization detector (PID). If headspace PID readings exceed 10 ppm above background, a sample will be collected for VOCs analysis. Field calibration, preventative maintenance, and standard operating

procedures (SOPs) for the PID are provided in Section 5.0. One soil sample will be collected per 2 acres and will be submitted to determine the grain size distribution (ASTM-D422), pH (ASTM-D4972), organic content (ASTM-D2974), nitrogen content, phosphorus and potassium (per American Society of Agronomy Method of Soil Analysis, and organic carbon content (ASTM-D2974). ASTM Methods are included as Attachment C.

The stratigraphic sequence observed at each borehole will be described on an Overburden Stratigraphy Log, an example of which is provided in Attachment A.

CRA will also complete a physical inspection of the landfill cover, identifying areas of vegetative stress, erosion (especially locations of deep gouges through the cover indicating continuous erosion), exposed waste, and settlement locations that will require additional soil cover. The findings from the inspection will be recorded in the field book and/or a Site plan.

#### **2.1.2.3     TEST PITS AND TEST PIT SAMPLING**

Five test pits will be excavated in the CDA to determine the depth of construction debris in land parcels not previously sampled. The test pit locations are shown on Figure 2.3 and are discussed further in Section 4.2 of the RD Work Plan. Test pits will be installed to visually identify and characterize subsurface materials in the CDA. During the Site reconnaissance, a field technician will record visual observations of the ground surface conditions within the CDA for the purpose of establishing an inventory of the surface debris and rubble present within the CDA. Test pit locations are approximate and will be modified based on field observations as necessary.

CRA understands that drums of toluene have historically been found within the CDA. It is anticipated that the proposed test pits will not encounter buried drums, however, excavation in the area of the CDA will be very slow and controlled. The excavation will progress in no deeper than 2 foot intervals and if a drum is encountered, the work will stop, the area and the drum will be secured and work in that area will stop. CRA will then prepare a drum management plan for USEPA review and approval.

An excavator or backhoe will be used to excavate the test pits in the CDA. The test pit excavation and sampling procedures are as follows:

1. Each test pit will be assigned a unique identification number. Prior to starting the test pit excavations, the locations of each test pit will be staked in the field using the locations identified in the RD Work Plan.
2. The area immediately adjacent to the test pit will be used for stockpiling excavated waste and soil. The excavation spoils will be placed on polyethylene sheeting downwind of field personnel and in such a manner that water runoff, if any, from the waste material will be directed back into the excavation. Soil/waste material temporarily stockpiled will be backfilled into open excavations before the contractor leaves the Site for the day.
3. The test pits will be approximately 6 feet deep. The lengths of individual test pits will be determined in the field by the field representative based on conditions encountered during excavation.
4. A photographic log will be recorded of each test pit during its progression. The photographic record will list the date of each photograph, a specific description of what the photograph depicts, its location, and the photographer.
5. The dimensions of each excavation and a description of the soils encountered during excavation will be recorded on a Test Pit Stratigraphy Log, an example of which is provided in Attachment A.
6. Soil samples will be collected from 0 to 2 ft bgs, from 2 to 4 ft bgs, and from 4 to 6 ft bgs each test pit. The specific area of soil selected for sampling and number of samples will be determined in the field by the field representative. Sample selection will be based on the visual appearance of the material (for example, color, staining, grain size) and field instrument measurements. The observations will be recorded in the Test Pit Stratigraphy Log. The samples will be collected directly from the bucket of the excavator.
7. A portion of each sample from the test pits will be placed in a separate container for headspace analysis. Results of the headspace analysis will be recorded in the Test Pit Stratigraphy Log.
8. Grab soil samples will be collected from the floor of the excavation, off of the bucket of the excavator and analyzed for TCL SVOCs and TAL metals including cyanide. The soil data will be compared to the IDEM Residential Default Closure Levels.
9. Each test pit will be backfilled with the excavation materials in reverse order to that in which they were removed. Each test pit location will be restored to match surface conditions prior to excavation to the extent possible. Each test pit

location will be restored to match surface conditions prior to excavation to the extent possible.

## **2.2      LANDFILL GAS/SOIL GAS SAMPLING**

A total of 27 soil gas probes will be installed at the Site, as shown on Figure 2.4 and as described in Section 4.3 of the RD Work Plan. Twenty-four soil gas probes will be installed along the northern, eastern, and southern property boundaries of the Site, and three soil gas probe nests will be installed adjacent to three residential buildings.

### **2.2.1      GAS PROBE INSTALLATION**

The soil gas probes will be installed using a 2-inch diameter Geoprobe® dual-tube direct push technique to minimize formation disturbance. Soil gas probes will be installed to a depth at least 3 feet above the local groundwater table. If the depth to the water table is not known, a pilot borehole will be drilled to confirm the depth of the water table and identify the depth of boring for the gas probe.

The soil gas probes will be comprised of 1/2-inch diameter Schedule 40 PVC continuous piping (i.e., no joints), a minimum 4 feet of screen perforations, and a minimum of 5 feet of riser pipe. Riser pipe lengths will vary with variations in groundwater elevations. The annulus of the perforated section of soil gas probe will be backfilled with 3/8-inch diameter clear stone to approximately 1 foot above the top of the screened interval. The annulus of the non-perforated riser above the clear stone will be backfilled with bentonite pellets to just below ground surface, and hydrated to seal the soil gas probe. The clear stone and bentonite will be placed as the Geoprobe® is withdrawn to ensure that the formation does not collapse around the screened interval or riser. The riser section of the soil gas probe will extend a minimum of 3 feet above ground surface. A lockable surface casing will be set in concrete at ground surface around each soil gas probe. A typical soil gas probe is presented on Figure 2.5.

Should soil gas probes be installed in waste, soil gas probe boreholes will not extend below the base of the waste. Should a soil gas probe borehole extend below the base of the waste, the borehole will be grouted through the penetrated depth prior to installation of the soil gas probe.

The soil gas probe nests will be installed using a 2 inch diameter Geoprobe® dual-tube direct push technique to minimize formation disturbance. Two separate boreholes will

be advanced for shallow and deep soil gas probes to be located within 2 feet of each other. The shallow soil gas probe will be installed to screen a depth of approximately 5 to 6 feet BGS, and the deep soil gas probe will be installed to screen a depth of approximately 8 to 9 feet BGS. The Geoprobe® screen implant (approximately 1-foot in length) will be inserted down the annulus of the drive rods and will be attached to the drive point at the bottom of the drive rods.

Geoprobe® screen implants will be used that are constructed of ¼-inch diameter stainless steel tubing, equipped with an anchor. The screen implants will be set at the bottom 1-foot of each borehole. The implant will be connected to ¼-inch diameter nylon sampling tubing of sufficient length to extend to ground surface. Once the implant is set in position the drive rods will be removed leaving the implant in the subsurface. While removing the drive rods, a sand pack of inert 10/20 silica sand will be placed around the implant to 6 inches above the screened interval. A 1 foot thick seal comprised of dry granular bentonite will be placed on top of the sand pack. The remainder of the borehole will be filled with pre-hydrated granular bentonite to ground surface. Each soil gas probe will extend a minimum of 3 feet above ground surface inside a lockable surface casing set in concrete at ground surface. Tubing will be terminated with a valve connection at the top of the protective casing. A typical soil gas probe nest is presented on Figure 2.5.

Typical soil gas probe stratigraphic and instrumentation logs are presented in Attachment A.

CRA will record soil sample characteristics from soil gas probe locations as follows:

- geologic conditions encountered, including soil classification (USCS) to be recorded on stratigraphic logs; and
- presence of/depth to the shallow groundwater table.

The following additional soil characteristics will be obtained from the soil gas probe nests to permit modeling of the potential vapor gas intrusion:

- porosity and water-filled porosity;
- dry bulk density;
- vapor permeability; and
- fraction of organic carbon content.



Immediately after installation of the SGPs, CRA will purge the equivalent of three times the dead volume (internal volume of the sampling apparatus, including the implant screen, and the tubing) plus the sand pack volume. Samples will not be collected from the SGPs until 48 hours after initial purging.

Soil samples collected from each borehole will be screened in the field for evidence of impact based on visual and olfactory observations and on undifferentiated volatile organic compound readings, as measured by a FID and a PID. Field calibration, preventative maintenance, and SOPs for the FID and PID are contained in Section 5.0.

### 2.2.2 GAS PROBE SAMPLING

Baseline soil gas sampling for the major constituent gases (i.e., LFG including methane, oxygen, carbon dioxide, and balance gases) will be conducted following installation of the soil gas probes. This includes soil gas pressure and gas quality. The water level will be monitored in each probe to confirm the absence or presence of water in the probe. Samples will be collected a minimum of 48 hours after probe installation.

After completion of the baseline soil gas-monitoring event, CRA will complete two additional rounds of monitoring for the major constituent gases. Subsequent monitoring events will use the same equipment and monitoring parameters as discussed for the baseline soil gas monitoring event.

Two seasonal monitoring events will be conducted to sample soil gas for trace gases, nitrogen and VOCs. Each sample for trace gases (carbon monoxide, hydrogen sulfide, and total non-methane organic compounds (NMOCs)), nitrogen and VOCs will use a 6-liter evacuated canister fitted with a laboratory calibrated critical orifice flow regulation device sized to allow the collection of the soil gas sample over a 1-hour sample collection time. Only canisters certified clean at the 100 percent level will be used for sampling so that data can be evaluated for the purpose of assessing potential human health risks due to vapor intrusion. The 1-hour sample collection time for a 6-liter capacity evacuated canister corresponds to a maximum soil gas sample collection flow rate of approximately 200 milliliters per minute (mL/min). This soil gas sample collection flow rate corresponds to the lower end of the maximum soil gas sample flow rate recommended in the soil gas sampling protocol recently developed by the State of California Advisory for Active Soil Gas Investigations, California EPA (CAEPA, 2003). A maximum flow rate of 200 mL/min is recommended to limit VOC stripping from soil, prevent the short-circuiting of ambient air from ground surface that would dilute the soil gas sample, and increase confidence regarding the location from which the soil gas

sample is obtained. The low flow rate of 200 mL/min provides the most representative sample of in situ conditions. Prior to sample collection, soil gas probe purging will be conducted at a maximum flow rate of 200 mL/min. Soil gas purging will entail the removal of approximately 3 times the "dead volume" of an individual soil gas probe to remove potentially stagnant air from the soil gas probe. This will ensure that the soil gas is representative of the formation being sampled. The "dead volume" will be calculated in accordance with IDEM guidance. For soil gas probe nests, the dead volume will be based on the volume of the implant screen and the nylon tubing of each individual soil gas probe. For typical soil gas probes, the dead volume will be based on the volume of the perforated and non-perforated PVC pipe.

Soil gas purging will be completed using a personal sampling pump. A personal sampling pump will be connected to a quick-connect sampling port located on the soil gas probe. Soil gas purging will commence by opening the valve to the soil gas probe and activating the personal sampling pump at a flow rate limited 200 mL/min or less.

Quality assurance/quality control (QA/QC) measures implemented during the soil gas sampling event will include leak testing, maintaining a minimum residual negative pressure in the evacuated canisters of approximately 1 to 5 inches of mercury following sample collection, collection of one field duplicate sample, and the analysis of an outdoor ambient air sample (see Section 2.2). A brief description of the leak testing procedures is provided below.

Leak testing will be performed to determine whether ambient air has infiltrated the sample collection system during sampling. The leak testing will consist of a two-step process. The first step, conducted prior to sample collection, will involve vacuum testing the sampling equipment after assembly to test the air-tightness of the assembly connections. The second step, conducted during sample collection, will involve placing paper towels soaked in a dilute solution of 99 percent pure isopropanol placed around the soil gas probe surface casing, ground surface immediately surrounding the surface casing, and sample assembly connections at the surface casing. The paper towels will be covered by a plastic sheet to shroud the soil gas probe and sampling assembly connections at ground surface. The shroud will retain vapors emitted from the isopropanol solution. Isopropanol will serve as the tracer compound and is included in the TO-15 list of VOCs. For the first step, the sampling assembly will be connected to include the purge pump in a valved tee-connection before connecting to the evacuated canister. Prior to purging the gas probe, the valve to the purge pump will be opened leaving closed the valve to the evacuated canister and the valve to the gas probe. The pump will be operated to ensure that it draws no air from the sampling assembly (i.e., creates a negative pressure, or vacuum within the sampling assembly), thus

establishing that all assembly connections are air-tight. Purging of the gas probe will then commence. Once purging is completed, the valve to the purge pump will be closed, and the second leak test step described above will be implemented. The valve to the evacuated canister will then be opened and sample collection will commence. The soil gas sample analytical results will be reviewed to ensure that significant isopropanol is not present in the sample, thus ensuring that ambient air did not infiltrate into the sample.

### 2.2.3 AMBIENT OUTDOOR AIR SAMPLING

A summary of the steps involved in the ambient outdoor air sampling protocol is presented below:

- The outdoor air sample will be collected using a 6-liter capacity evacuated canister fitted with a laboratory calibrated critical orifice flow regulation device sized to allow the collection of the soil vapor sample over a 30-minute sample collection time. The 30-minute sample collection time for a 6-liter capacity evacuated canister corresponds to a maximum sample collection flow rate of approximately 200 mL/min.
- The canister will be positioned at a height of 3 feet above ground level and upwind of the Site during sample collection.
- At approximately 25 minutes after start of sample collection, the valve to the canister will be closed and the canister vacuum will be measured using a vacuum gauge provided by the laboratory. A residual vacuum in the evacuated canisters of approximately 1 to 5 inches Hg will be achieved to ensure a sufficient sample volume is collected. A canister residual vacuum above this value will require continued sampling until vacuum reading is below the threshold.
- The canister will be located away from any obvious potential emission source such as automobiles, sewer vents, furnace vents, etc., to the extent practical.
- The canisters will be labeled noting the unique sample designation number, date, time, and sampler's initials. A bound field logbook will be maintained to record all sampling data.

### 2.3 GROUNDWATER INVESTIGATION AND MONITORING

The groundwater investigation will be performed in phases based on the portion of the Site being investigated and the target depths of the investigation. A phased approach

permits information collected during the initial stages of the investigation to be used to guide subsequent phases of the investigation. Work for each of these phases will consist of initial vertical aquifer sampling (VAS) and subsequent monitoring well installation based on the results of the VAS.

Section 2.0 in the RD Work Plan describes the regional and Site hydrogeology. The following hydrostratigraphic units exist at the Site based on available information:

1. the unconfined upper aquifer;
2. a confining clay layer; and
3. a confined or semi-confined lower aquifer.

The sections below present procedures for field tasks related to the above phases of groundwater investigations.

VAS will be completed at all proposed monitoring well locations to delineate the concentration and extent of groundwater contamination. New monitoring wells will be designed and the appropriateness of existing monitoring wells will be evaluated, based on the results of the VAS. Hydraulic information will be collected to evaluate the groundwater flow regime in the vicinity of the Site. Groundwater sampling of the existing and proposed wells will also be completed to further characterize hydrogeologic conditions. The specific rationale for well locations is presented in Section 4.0 of the RD Work Plan.

### 2.3.1 VERTICAL AQUIFER SAMPLING

VAS will be conducted to determine the vertical extent of contamination and to identify the appropriate screen intervals for subsequent monitoring wells. The proposed locations for the first round of VAS samples are shown on Figure 2.7, and discussed in Section 4.4 of the RD Work Plan. VAS samples will be collected at 10-foot intervals beginning 5 feet below the water table. The depth to the water table will be determined by visual examination of soil samples for saturated conditions or and/or the measurement of standing water inside the drilling equipment. In the case of VAS at existing monitoring wells the depth to the water table will be determined by measuring the depth to water in the adjacent shallow monitoring well. VAS samples will be analyzed for TCL VOCs and selected general chemistry parameters. The well screen interval for monitoring wells will be selected to coincide with the zone of highest contamination observed in the VAS samples collected at each boring. Also, sentry wells

will be installed beyond the current limits of groundwater contamination to monitor for any future plume expansion. In areas where contamination is not present the well screen depth will be selected based on the distribution of any nearby contamination and the local hydrostratigraphy.

It is anticipated that different drilling techniques will be used for VAS, based on the depth of the boring and ground conditions. Direct push drilling techniques and HSA drilling should be appropriate for depth of less than 60 feet bgs. Rotosonic drilling techniques will be used for deeper VAS investigations.

#### **2.3.1.1 VERTICAL AQUIFER SAMPLING BY GEOPROBE**

The direct push VAS procedure will use the Geoprobe® Screen Point 16 (SP16) groundwater sampler, or equivalent, as follows:

1. The direct push drill rig will advance the borehole using methods consistent with ASTM Standard D6724-01 included in Attachment C.
2. The direct push borehole will be advanced from ground surface to a total depth of up to 60 feet bgs or as ground conditions allow. Soil samples will be collected using Geoprobe® MacroCore® sampling techniques or equivalent. Soil samples will be collected throughout the entire length of the borehole.
3. Representative samples will be logged immediately after opening the acetate liner. Field measurements of undifferentiated VOCs will be conducted by placing representative soil samples into a closed sample container and allowing them to equilibrate. The VOCs in the headspace will then be measured by placing the wand of the PID into the headspace. Field calibration, preventative maintenance, and SOPs for the PID are contained in Section 5.1.
4. The soil core will be logged by CRA personnel and soils will be classified using the USCS in accordance with ASTM Method D-2488 (ASTM Methods are in Attachment C). Samples will be described on an Overburden Stratigraphy Log, an example of which is in Attachment A.
5. Upon reaching the total depth of the borehole the downhole equipment will be removed from the borehole and the borehole will be backfilled with pure bentonite slurry grout.
6. VAS will be conducted at 10-foot intervals beginning no deeper than 5 feet below the water table. A pre-cleaned Geoprobe® SP16 groundwater sampler will be assembled by the as per manufacturer's operational procedure.

7. The Geoprobe® SP16 groundwater sampler will be advanced to the target depth. The Geoprobe SP16 is a direct push groundwater sampling device that consists of a well screen inside a steel sheath that is driven to depth and then deployed by retracting the steel sheath and exposing the well screen directly to the formation.
8. New 1/4-inch diameter tubing will be installed and attached to a peristaltic pump. Groundwater will be purged from the Geoprobe® SP16 groundwater sampler using the peristaltic pump. Field measurements of turbidity will be collected at approximate 5-minute intervals. All field measurements will be recorded in the field book.
9. Purging will continue until the turbidity of the purge water is equal to or less than 5 nephelometric turbidity units (NTUs). In the event that turbidity values of less than 5 NTUs cannot be achieved, purging may also be considered complete if a minimum of 10 screen point well volumes have been purged or three successive turbidity readings are within 10 percent of their average value.
10. Once turbidity has stabilized groundwater samples will be collected directly from the discharge line in laboratory-supplied, analyte-specific sample containers and preserved according to laboratory requirements. Groundwater samples collected for VOC analysis will be collected from the tubing before it reaches the pump head.
11. VAS samples will be analyzed for TCL VOCs and selected general chemistry parameters on a standard turnaround time. QC samples will be collected for chemical analysis as discussed in Section 3.0 and the QAPP. Samples will be handled as discussed in Section 4.0.
12. The Geoprobe® SP16 groundwater sampler will be decontaminated between samples following the procedures in Section 6.0.
13. Upon reaching the total depth of the borehole the downhole equipment will be removed from the borehole and the borehole will be backfilled with pure bentonite slurry grout.
14. All downhole equipment such as drill rods and sample tools will be decontaminated as discussed in Section 6.0.
15. Drill cuttings and decontamination water will be managed as discussed in Section 7.0.

### 2.3.1.2 VERTICAL AQUIFER SAMPLING BY HOLLOW STEM AUGER

For HSA boreholes VAS will be collected using a SimulProbe® sampler. The methodology is as follows:

1. The HSA drill rig will advance a 4 1/4-inch inside diameter hollow-stem auger.
2. The HSA borehole will be advanced from ground surface to a total depth of up to 100 feet bgs or as ground conditions allow.
3. VAS will be conducted at 10-foot intervals beginning no deeper than 5 feet below the water table.
4. Once the borehole has reached the target depth for the groundwater sample, the pre-cleaned Simulprobe® will be assembled by the as per manufacturer's operational procedures.
5. The drill rods and the auger plug will be removed from the borehole. The Simulprobe® sampler will be attached to the drill rods and suspended inside the HSA.
6. The Simulprobe® sampler will then be pressurized using nitrogen gas and lowered to the bottom of the boring. The Simulprobe® sampler will be pushed or driven 21 inches into the formation beyond the HSA to collect a soil sample.
7. The SimulProbe® sampler will then be pulled back 2 to 3 inches to expose the screen. The SimulProbe® sampler will then be de-pressurized, allowing groundwater to enter tool under ambient hydrostatic pressure. The fill rate will be observed by placing the open end of the gas discharge line into a bucket of water and observing the bubbles produced as the sample canister fills.
8. After sufficient groundwater sample has been collected, the SimulProbe® sampler will be re-pressurized and then raised to a few feet below the top of the HSA.
9. The SimulProbe® sampler will be de-pressurized inside the HSA.
10. The SimulProbe® sampler will then be removed from the HSA and opened.
11. The soil sample will be retrieved from the SimulProbe® sampler and logged by CRA personnel. Soils will be classified using the USCS in accordance with ASTM Method D-2488 (see Attachment C).
12. Field measurements for VOCs will be conducted by placing representative soil samples into a closed sample container and allowing them to equilibrate. The VOCs in the headspace will then be measured by placing the wand of the PID into the headspace. Field calibration, preventative maintenance, and SOPs for the PID are contained in Section 5.1.

13. While maintaining the water canister in an upright position to minimize sample agitation, the groundwater sample for each interval will be collected directly from the Simulprobe™ sampler into the laboratory-supplied sample containers using disposable decanting tubes.
14. VAS samples will be analyzed for TCL VOCs and selected general chemistry parameters on a standard turnaround time. QC samples will be collected for chemical analysis as discussed in Section 3.0 and the QAPP. Samples will be handled as discussed in Section 4.0.
15. The Simulprobe™ sampler will be decontaminated between samples following the procedures in Section 6.0.
16. Upon reaching the target depth the HSA will be removed from the borehole and the borehole will be backfilled with pure bentonite slurry grout using a tremie pipe.
17. All downhole equipment such as augers and drill rods will be decontaminated as discussed in Section 6.0.
18. Drill cuttings and decontamination water will be managed as discussed in Section 7.0.

#### 2.3.1.3 VERTICAL AQUIFER SAMPLING BY ROTOSONIC

Rotosonic drilling methods will be required for deeper sampling locations (i.e., greater than approximately 60 feet). Typically they will be installed adjacent to a shallower VAS borehole installed using direct push or HSA methods. For all Rotosonic boreholes VAS samples will be collected using the SimulProbe® sampler. The procedures are as follows:

1. The rotosonic drill rig will advance a 4-inch diameter (nominal) core barrel for sampling and will also advance a 6-inch diameter outer casing to ensure the borehole remains open when the core is retrieved.
2. The rotosonic borehole will be advanced from ground surface to a total depth of up to 150 feet bgs. Soil samples will be collected commencing at the bottom depth of the previously installed shallow VAS. The nominal 4-inch core barrel is advanced from 10 to 20 feet ahead of the nominal 6-inch diameter outer casing without the use of drilling fluids or air. The outer casing is then advanced to a depth of 10 feet less than the depth of the core barrel injecting some water to maintain a fluid head. The core sample is then retrieved from the inner core barrel.



3. Core samples will be taken directly from the core barrel attached to the end of the drill string and extruded into 10-foot long cylindrical bags. Field measurements for undifferentiated VOCs will be conducted by placing representative soil samples into a closed sample container or a ziplock bag and allowing them to equilibrate. The VOCs in the headspace will then be measured by placing the wand of the PID into the headspace. Field calibration, preventative maintenance, and SOPs for the PID are contained in Section 5.0.
4. The soil core will be logged by CRA personnel and soils will be classified using the USCS in accordance with ASTM Method D-2488 (ASTM Methods are in Attachment C). Core from each borehole will be described on an Overburden Stratigraphy Log, an example of which is in Attachment A.
5. VAS will be conducted at 10-foot intervals beginning no deeper than 5 feet below the bottom of the previously installed direct push or HSA borehole. Once the borehole has reached the target depth for the groundwater sample, the pre-cleaned Simulprobe® will be assembled by the as per manufacturer's operational procedure.
6. The 4-inch casing will be removed from the borehole. The Simulprobe® sampler will be attached to the drill rods and suspended inside the casing.
7. The Simulprobe® sampler will then be pressurized using nitrogen gas and lowered to the bottom of the boring. The Simulprobe® sampler will be pushed or driven 21 inches into the formation beyond the casing to collect a soil sample.
8. The SimulProbe® sampler will then be pulled back 2 to 3 inches to expose the screen. The SimulProbe® sampler will then be de-pressurized, allowing groundwater to enter tool under ambient hydrostatic pressure. The fill rate will be observed by placing the open end of the gas discharge line into a bucket of water and observing the bubbles produced as the sample canister fills.
9. After sufficient groundwater sample has been collected, the SimulProbe® sampler will be re-pressurized and then raised to a few feet below the top of the casing.
10. The SimulProbe® sampler will be de-pressurized inside the casing.
11. The SimulProbe® sampler will then be removed from the casing and opened.
12. The soil sample will be retrieved from the SimulProbe® sampler and logged by CRA personnel. Soils will be classified using the USCS in accordance with ASTM Method D-2488 (see Attachment C).
13. While maintaining the water canister in an upright position to minimize sample agitation, the groundwater sample for each interval will be collected directly

from the Simulprobe™ sampler into the laboratory-supplied sample containers using disposable decanting tubes.

14. VAS samples will be analyzed for TCL VOCs and selected general chemistry parameters on a standard turnaround time. QC samples will be collected for chemical analysis as discussed in Section 3.0. Samples will be handled as discussed in Section 4.0.
15. The Simulprobe™ sampler will be decontaminated between samples following the procedures in Section 6.0.
16. Upon reaching the target depth and collecting the final VAS sample the HSA will be removed from the borehole and the borehole will be backfilled with pure bentonite slurry grout using a tremie pipe.
17. All downhole equipment such as augers and drill rods will be decontaminated as discussed in Section 6.0.
18. Drill cuttings and decontamination water will be managed as discussed in Section 7.0.

### 2.3.2 MONITORING WELL INSTALLATION

The design of the permanent monitoring wells will be based on the VAS results. It is anticipated that monitoring wells will be installed at a variety of depths to fully delineate the nature and extent of groundwater contamination and to characterize vertical groundwater migration beneath the Site. The well screen interval for permanent monitoring wells will be based on several factors:

- a new shallow monitoring well will be installed across the water table if there is no existing water table monitoring well;
- a monitoring well will be installed at a depth corresponding to the zone of maximum contamination observed in the VAS samples collected at each boring; and
- where appropriate, monitoring wells will be installed beyond the current horizontal and vertical limits of groundwater contamination to act as sentry wells to identify future plume expansion, if any.

It is anticipated that the proposed shallow and intermediate monitoring wells that will be installed less than 100 feet bgs will be installed using the HSA drilling method. The deep monitoring wells will be installed using the rotosonic method. A typical monitoring well construction detail is shown on Figure 2.8. In the event that attempts to install the boreholes for construction of the shallow monitoring wells using HSA drilling

techniques are unsuccessful, roto sonic techniques will be used. All monitoring wells will be surveyed in accordance with Section 2.1.1.

All downhole equipment such as augers, drill casings, drill rods, and split-spoon samplers will be decontaminated as discussed in Section 6.0. Drill cuttings and decontamination water will be managed as discussed in Section 7.0.

New monitoring wells will be constructed of 2-inch diameter, 0.01-inch (10 slot), 5-foot long PVC screens with threaded end caps. Monitoring well risers will be 2-inch diameter Schedule 40 PVC with flush-threaded joints.

Shallow and intermediate monitoring well installation is discussed in Section 2.3.2.1. Deep monitoring well installation is discussed in Section 2.3.2.2.

#### **2.3.2.1     SHALLOW AND INTERMEDIATE MONITORING WELL INSTALLATION**

Borings will be advanced using 4 1/4-inch inside diameter HSA drilling techniques. Soil samples will be collected from the proposed well screen interval to confirm stratigraphic conditions. Soil samples will be collected using 2-inch diameter split-spoon samplers, using the techniques described in ASTM Method D-1586. Soil samples will be classified using the USCS in accordance with ASTM Method D-2488 (see Attachment C). The stratigraphic sequence observed at each borehole will be described on an Overburden Stratigraphy Log, an example of which is in Attachment A.

A bottom plug will be utilized to keep out soils and/or water that have a tendency to plug the bottom of the augers during drilling. If flowing sands are encountered, potable water may be poured into the augers to equalize the pressure to keep the formation materials and water from coming up into the auger once the bottom plug is removed.

The well screen and riser will be installed through the hollow-stem augers. A filter pack consisting of silica sand (20-40 mesh) will be installed approximately 1 foot below the bottom of the well screen to 2 feet above the top of the well screen. Approximately 2 to 3 feet of bentonite pellets will be placed above the filter sand to provide a seal for the pure bentonite slurry grout.

In the intermediate monitoring wells, the remaining annulus above the bentonite pellets layer will be backfilled with pure bentonite slurry grout to within 3 feet of ground surface. A tremie pipe will be used to place the backfill bentonite grout. Bentonite

gravel will be used in place of bentonite grout in the shallow, water table monitoring wells. Any bentonite pellets placed above the water table will be hydrated as they are installed.

In the intermediate and shallow monitoring wells, the uppermost 3 feet of the boring annulus will be filled with concrete, forming a pad of at least 2-foot diameter at ground surface that slopes away from the well. A locking protective steel casing will be set in the concrete over the well riser. Where traffic conditions and other land use considerations allow, the well casing will extend to approximately 2.5 feet above ground surface, and will be fitted with a hinged lockable cap. The well identification number will be permanently marked on the outer casing of all newly installed and existing monitoring wells. If required, protective bollards will be installed to protect the monitoring wells from vehicular traffic.

#### 2.3.2.2 DEEP MONITORING WELL INSTALLATION

The deep monitoring wells (screened at depths greater than 100 feet bgs) will be installed using rotosonic drilling method using a nominal 6-inch inside-diameter casing.

The rotosonic monitoring well installation procedure is as follows:

1. The rotosonic drill rig will advance a 4-inch diameter (nominal) core barrel for sampling and will also advance a 6-inch diameter outer casing for the construction of the monitoring wells.
2. The rotosonic borehole will be advanced from ground surface to a total depth of up to 150 feet bgs. Soil samples will be collected from the proposed well screen interval to confirm stratigraphic conditions.
3. The screened interval for the monitoring well will be selected based on the results of the VAS sampling. The well screen and riser will be installed through the 6-inch diameter outer casing after the final run 4-inch diameter core barrel is completed and the core barrel is removed. A filter pack consisting of silica sand (20-40 mesh) will be installed approximately 1 foot below the bottom of the well screen to 2 feet above the top of the well screen. Approximately 2 to 3 feet of bentonite pellets will be placed above the filter sand to provide a seal for the pure bentonite slurry grout.
4. The boring annulus above the bentonite gravel layer will be backfilled with bentonite grout to within 3 feet of ground surface. A tremie pipe will be used to emplace the backfill bentonite grout.

5. The outer casing will be removed from the borehole as the well screen and riser, sand pack and bentonite seal are installed.
6. The uppermost 3 feet of the boring annulus will be filled with concrete, forming a pad of at least 2-foot diameter at ground surface that slopes away from the well. A locking protective steel casing will be set in the concrete over the well riser. Where traffic conditions and other land use considerations allow, the well casing will extend to approximately 2.5 feet above ground surface, and will be fitted with a hinged lockable cap. The well identification number will be permanently marked on the outer casing of all newly installed and existing monitoring wells.

### 2.3.3 MONITORING WELL DEVELOPMENT

The newly-installed monitoring wells will be developed using a combination of methods, not sooner than 48 hours after grouting is completed. In addition, existing monitoring wells will be redeveloped prior to groundwater sampling. Development will continue until the turbidity of the development water is equal to or less than 5 NTUs. In the event that turbidity values of less than 5 NTUs cannot be achieved, well development may also be considered complete if all of the following conditions are met:

1. a minimum of 10 well volumes have been removed in addition to any volume of water or fluid that was introduced into the well and/or formation during construction and development; and
2. temperature, pH, and conductivity have stabilized to plus or minus 10 percent over a minimum of at least three consecutive well volumes.

Initially, CRA will pump groundwater from the wells using either a submersible pump or an inertial pump. After the initial pumping, CRA will gently surge the wells. CRA will accomplish initial surging by either raising and lowering the submersible pump throughout the screened interval, bailing the well with a bailer, and/or backwashing the well. If CRA backwashes the well, it will be with either potable water or development water after the fines have settled out. Following the initial surging, CRA will pump the wells again. If significant turbidity persists, CRA will surge the monitoring wells with a mechanical surge block and the well will be over pumped.

Mild surging will be used if necessary. A submersible pump may also be used to develop the wells by raising and lowering the pump intake throughout the screened interval.

Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter. Temperature, pH, and conductivity will be measured using a YSI Model 3560 instrument. Alternatively, equivalent instruments may be used. Field calibration and preventative maintenance procedures, and SOPs are contained in Section 5.0. Decontamination procedures for the surge block and submersible pump are contained in Section 6.0. Decontamination fluids and purge water will be managed as described in Section 7.0.

Development data will be recorded on a Well Development and Stabilization Form, an example of which is in Attachment A. Groundwater sampling will not proceed until at least 7 days after the completion of well development to allow for equilibrium of aquifer conditions to be re-established.

#### 2.3.4 HYDRAULIC MONITORING

##### Monitoring Wells

Hydraulic monitoring will be performed at all monitoring wells at the time of each groundwater sampling event. The initial frequency of groundwater sampling will be quarterly. All hydraulic monitoring data will be collected within a 24-hour period for each monitoring event.

Groundwater elevation measurements will be collected using a Solinst Model 101 water level indicator, or equivalent, and a reference point of known elevation on the monitoring well riser to determine the distance between the reference point and the water level in the well. The water level indicator is a battery-powered, self-contained instrument equipped with a cable and sensor that activates a buzzer and a light when it comes in contact with the water. The depth to water is read from permanent 0.01-foot increment markings on the cable. The reference point will consist of an indelible mark on the highest point of the well riser. All measurements will be recorded in a field logbook or on standard forms. Groundwater elevation data may also be recorded electronically, to facilitate entry into the data base. Field calibration, preventative maintenance, and SOPs are contained in Section 5.0.

The water level indicator will be decontaminated as discussed in Section 6.0. Decontamination water will be managed as discussed in Section 7.0.

## Surface Water

Three staff gauges previously existed at the Site, one in each of the Little Pond, the L Pond and the Quarry Pond. Figure 2.9 shows the locations of the existing staff gauges. The locations of the three existing staff gauges will be examined during the monitoring well reconnaissance activities. If the staff gauges are missing or damaged they will be replaced, labeled, re-surveyed and used in future water level monitoring. New staff gauges will be installed in a manner appropriate with the depth of the pond to maintain the staff gauges in a stable position.

Hydrologic data will be collected during the implementation of the RD Work Plan. Manual water level measurements will be collected using a tape measure accurate to  $\pm 0.01$  feet. The measurements will be made from the survey mark or from the top of the staff gauge. The depth to surface water will be converted to elevations based on the surveyed elevation at each staff gauge location.

Surface water monitoring will be conducted at the Site in order to verify groundwater flow direction and groundwater recharge/discharge of Site surface water. Surface water elevations will be measured in conjunction with synoptic groundwater elevation monitoring rounds.

### **2.3.5      GROUNDWATER SAMPLING**

Monitoring wells to be sampled include selected existing monitoring wells and all proposed monitoring wells. The protocol described below applies minimal drawdown techniques to obtain samples that are representative of groundwater moving through the subsurface under natural conditions. Groundwater samples will be collected and analyzed for the parameters listed in Table 2.1.

All downhole equipment, such as the water level indicator, dissolved oxygen probe, and pumps, will be decontaminated as discussed in Section 6.0. Purge water and decontamination water will be managed as discussed in Section 7.0.

## Well Purging

The minimal drawdown purging protocol will be as follows:

1. The groundwater level will be measured to the nearest 0.01 foot using a pre-cleaned Solinst Model 101 electric water level indicator or equivalent. Field calibration, preventative maintenance, and SOPs are contained in Section 5.0.
2. Purging will be conducted using a Grundfos or equivalent 2-inch diameter submersible electric pump. The pump discharge line will be polyethylene and dedicated to the well. The submersible electric pump will be secured to nylon rope (dedicated to the well). The submersible electric pump will be positioned such that the pump intake corresponds to the middle of the well screen and/or at least 2 feet above the level of any sediment measured in the well.
3. Purging of the monitoring well will be conducted using a pumping rate, designed to minimize drawdown, typically between 100 mL/min and 500 mL/min. Initial purging will begin using a pumping rate at the lower end of this range. The groundwater level will be measured while purging to ensure that less than 0.3 foot of drawdown occurs. The pumping rate may be gradually changed depending upon the amount of drawdown and the behavior of the stabilization parameters (see item 5 below). Pumping rate adjustments generally will be made within 15 minutes from the start of purging and then should remain constant for the duration of purging. While purging, the pumping rate and groundwater level will be measured and recorded every 10 minutes (or as appropriate). If it is apparent that stabilization of the purged groundwater (see item 5 below) will not be achieved rapidly, these measurements may be made at longer time intervals to allow field staff to perform other sampling activities.
4. Stabilization of the purged groundwater is necessary prior to sampling to ensure that the samples obtained are representative of groundwater in the subsurface only and not influenced by stagnant groundwater stored in the well casing. The field parameters pH, temperature, conductivity, oxidation-reduction (redox) reaction potential (ORP), dissolved oxygen (DO), and turbidity will be monitored while purging to evaluate the stabilization of the purged groundwater. The field parameters will be measured and recorded every 10 minutes (or as appropriate) using the Monitoring Well Purging Record form, an example of which is in Attachment A. Stabilization will be considered to be achieved when three consecutive readings for each parameter are within the following limits:
  - pH  $\pm 0.1$  pH units of the average value of the three readings;
  - temperature  $\pm 3$  percent of the average value of the three readings;



- conductivity       $\pm 0.005$  milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity  $< 1$  mS/cm and  $\pm 0.01$  mS/cm of the average value of the three readings for conductivity  $> 1$  mS/cm;
  - ORP                       $\pm 10$  millivolts (mV) of the average value of the three readings;
  - DO                         $\pm 10$  percent of the average value of the three readings; and
  - turbidity                 $\pm 10$  percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU).
5. Conductivity, pH, temperature, and ORP will be monitored using a YSI Model 3560 instrument. Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter. Dissolved oxygen will be measured using a YSI Model 52 instrument. Alternatively, equivalent instruments may be used. Field calibration, preventative maintenance, and SOPs are contained in Section 5.0. At the start of purging, the purge water will be visually inspected for water clarity prior to connecting the flow-through-cell. If the purge water appears turbid, purging will be continued until the purge water becomes visibly less turbid before connecting the flow-through-cell. While purging, the meter readings will be monitored for evidence of meter malfunction. The following are common indicators of meter malfunctions:
- DO above solubility [e.g., oxygen solubility is approximately 11 milligrams per liter (mg/L) at 10° Celsius] may indicate a DO meter malfunction;
  - negative ORP and DO greater than 1 to 2 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have positive ORP and DO greater than 1 to 2 mg/L under oxidizing conditions); and
  - positive ORP and DO less than 1 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have negative ORP and DO less than 1 mg/L under reducing conditions).
6. Meter calibration fluids will be available for meter re-calibration in the field, if necessary.
7. In general, stabilization of the individual field parameters is expected to occur in the order listed above. Should stabilization not be achieved for all field parameters, purging will be continued until a maximum of 10 well screen volumes have been purged from the well. After purging 10 well screen volumes, purging will be continued if the purge water remains visibly turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the

stabilization criteria listed above and appear to be approaching stabilization. In the event the monitoring well does not stabilize after the removal of 10 well screen volumes, the groundwater sample will be collected.

8. In the event that the groundwater recharge to the monitoring well is insufficient to conduct the minimal drawdown protocol, the well will be pumped dry and allowed to sufficiently recharge prior to sampling. Wells which are purged dry will not be subject to the above purging criteria.

### Groundwater Sampling

Following purging and stabilization, groundwater sampling will be conducted using the following procedures:

1. A new pair of disposable latex gloves will be used for each sample collected.
2. The flow-through-cell will be disconnected prior to obtaining the sample. The discharge line from the pump will be positioned at the base of the sample bottle. All required preservatives will be added to the samples in the manner consistent with the appropriate methodology by either placing the preservative in the sample containers prior to sampling or adding at the sample location immediately after collection. The sample bottle will be filled from the bottom to the top and will be allowed to overflow before sealing (overflow is not recommended if the sample bottles have been prepared with preservatives prior to sample collection). Samples will be collected in the following order:
  - VOCs; and
  - inorganics and general chemistry.
3. Each VOC sample vial will be inspected for the presence of bubbles. If bubbles are observed, the sampler will attempt to add sample volume to the vial to remove the bubbles. If bubbles continue to form, indicating effervescence, the sample will be discarded and recollected. The laboratory will be notified that the samples are unpreserved and the analyses will be completed within the appropriate holding time (i.e., 7 days).
4. Parameters that require filtering will be collected following the attachment of a disposable 0.45 µm in-line filter to the discharge tubing.
5. All equipment used during sampling which may have come in contact with potentially contaminated waters will be decontaminated. Nitrile gloves used during the collection of the samples will be disposed of. The pump discharge line and air supply line will either be dedicated and left hanging in the well or disposed of after the well has been sampled.

6. QC samples will be collected for chemical analysis as discussed in Section 3.0. Samples will be handled as discussed in Section 4.0.

### 2.3.6 MONITORING WELL ABANDONMENT

After the long-term groundwater monitoring program is established there may be monitoring wells that are no longer required for the groundwater remediation. USEPA and IDEM approval will be obtained before the monitoring well abandonment proceeds.

State Rule 312 IAC 13-10-2 provides procedures for water well abandonment. The monitoring well abandonment procedures presented below are generally consistent with State Rule 312 IAC 13-10-2. A qualified contractor licensed in the State of Indiana will undertake the well abandonments.

Wells will be abandoned by pressure grouting in place using the tremie method. The grouting material will be one of the following mixed in accordance with the manufacturer's instructions:

1. neat cement;
2. concrete grout;
3. bentonite chips;
4. bentonite pellets; or
5. bentonite grout.

The tremie pipe will be at least 1-inch inside diameter.

Prior to beginning the well abandonment, the volume of the well installation should be calculated. As the injection of the grouting material proceeds, the volume injected will be compared to this calculated well volume to ensure that the volume of material used is at least equivalent to the volume of the well.

The procedure for abandonment of wells is:

1. Remove any dedicated equipment from the monitoring well to determine its total depth. Compare this to the well log to confirm the well identity.
2. Install the tremie pipe into the well to a depth within 2 feet of the installed bottom depth of the well screen.

3. Inject the grouting material into the well through the tremie pipe, gradually raising the pipe to ensure the well is filled from bottom to top.
4. Measure the depth to the grout periodically to ensure bridging does not occur.
5. Continue injection until the entire length of riser pipe is filled with grouting material and return is seen at the ground surface.
6. Allow grouting material to stabilize within the well and add additional material until the level remains within 2 feet of the ground surface.
7. Remove protective casings and surface seals not previously removed and cut the well riser at least 2 feet below the ground surface.
8. Fill the open excavation or annular space above the cut riser with material consistent with the surrounding area.
9. Restore the ground surface consistent with the surrounding area.

Decontamination procedures for the drilling equipment are contained in Section 6.0. Decontamination fluids and other wastes will be managed as described in Section 7.0.

Following the completion of the well abandonment program, a report will be prepared and submitted to USEPA and IDEM. The report will present the field activities and will include records of the well abandonment.

### 3.0 FIELD QUALITY CONTROL SAMPLING

#### 3.1 GENERAL

The sampling and analysis program associated with the RD Work Plan is summarized in Table 2.1. A summary of field QC sampling for laboratory chemical analysis and summary of the frequency of each type of field QC sample to be collected for each investigative activity is included in Table 3.1.

The following types of field QC samples will be collected for laboratory chemical analysis:

- field duplicate samples;
- equipment blank/decon water samples;
- matrix spike/matrix spike duplicate (MS/MSD) samples; and
- trip blank samples.

Each type of field QC sample for laboratory chemical analysis is discussed below.

#### 3.2 FIELD DUPLICATE SAMPLES

During the RD, blind field duplicate samples will be collected and submitted to the laboratory. Field duplicate samples will be collected in a manner whereby as the sample fraction for each parameter is collected, the sample medium will be equally split between the investigative fraction and the duplicate fraction for that parameter. VOC fractions for aqueous samples will be filled continuously until an individual vial is completely filled before filling a vial for a duplicate sample. One field duplicate will be collected for each 10 or fewer investigative samples submitted.

#### 3.3 EQUIPMENT BLANK SAMPLES

Equipment blank samples will be collected for any sampling activity that requires equipment decontamination. One equipment blank will be collected for each ten or fewer investigative samples submitted.

The equipment blank will be obtained by passing analyte-free laboratory-supplied, deionized water through a cleaned sampling apparatus (i.e., pump or sampler) and collecting it in a clean container.

### 3.4 MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES

MS/MSD sample volumes are additional sample aliquots provided to the laboratory to evaluate the accuracy and precision of the sample preparation and analysis technique.

Two times the normal sample aliquot is required for VOCs, SVOCs, pesticides, and PCBs to conduct MS/MSD analyses. No additional sample volume is required for inorganics or general chemistry parameters. Sample collection is identical to the technique described for collection of field duplicates. Sample labeling identifies the respective sample location and each additional container which is labeled as the "MS/MSD" volume.

One MS/MSD sample will be collected for each 20 or fewer investigative samples submitted.

### 3.5 TRIP BLANK SAMPLES

Trip blank samples will be used to determine if the sample shipping or storage procedures have influenced the analytical results. Trip blanks will be prepared by the laboratory using deionized water and preservative and sent to the Site in the shipping container(s) designated for the project. These samples will be kept with the investigative samples, then submitted to the laboratory for analysis with the investigative samples. The samples will not be opened.

Trip blanks will be analyzed for TCL VOCs only. One trip blank will be submitted for each cooler containing sample media for analysis of aqueous VOCs.

#### 4.0 SAMPLE CUSTODY AND DOCUMENT CONTROL

CRA follows the USEPA Region 5 sample custody protocols described in "NEIC Policies and Procedures", EPA-330/9-78-001-R, revised August 1991. This custody is segregated into three parts: sample collection; laboratory analysis; and final evidence files. Final evidence files, including all originals of laboratory reports, are maintained under document control in a secure area.

A sample or evidence file is in a person's custody if:

- the item is in actual possession of a person; or
- the item is in the view of the person after being in actual possession of the person; or
- the item was in actual physical possession of the person and is secured in an appropriate container and arrangements are made to transport it to the laboratory via a bonded courier; or
- the item is in a designated and identified secure area.

#### 4.1 SAMPLE LABELING

Each sample container will be labeled with a unique sample number that will facilitate tracking and cross-referencing of sample information and will be recorded in the field logbook. The unique sample number will be recorded with the sample location in the field logbook at the time of sample collection. The field logbook will form part of the permanent field record. The sample numbering system to be used is described as follows (the information entered on the sample labels will be printed by the field sampler):

Example:      GW-LOC-MMDDYY-D

Where:

- |        |  |
|--------|--|
| GW     | - designates types of sample (GW-groundwater, S-soil, SW-surface water, SD-sediment);  |
| LOC    | - designates sample location (i.e., MW-1, BH-1, etc.);   |
| MMDDYY | - designates date of collection presented as month, day, year; and   |
| D      | - designates type of field QC sample (D-field duplicate, E-equipment blank). This suffix will only be used for field QC samples. |

Trip blank samples also will be numbered with a unique sample number. The sample numbering system to be used for such samples is described as follows (the information entered on the sample labels will be printed by the field sampler):

Example:

TRIP BLANK - MMDDYY-N

where:

- MMDDYY - designates date of collection presented as month, day, year; and  
N - designates sequential number of each type of the two samples, starting with 1 at the beginning of the RD field activities.

An example of the sample label is provided on Figure 4.1.

#### **4.2 FIELD CHAIN OF CUSTODY PROCEDURES**

The sample packaging and shipment procedures summarized below will insure that the samples will arrive at the laboratory with the chain of custody intact. The Field QA Officer will be responsible for oversight of field documentation procedures.

##### **4.2.1 FIELD PROCEDURES**

1. The field sampler is personally responsible for the care and custody of the samples until they are transferred to another individual or properly dispatched to the laboratory. As few people as possible should handle the samples.
2. All containers will be labeled with unique sample numbers.
3. Sample labels will be completed for each sample using waterproof ink.

##### **4.2.2 FIELD LOGBOOKS/DOCUMENTATION**

Field logbooks will provide the means of recording data collecting activities performed. As such, entries will be described in as much detail as possible so that persons going to the Site could reconstruct a particular situation without reliance on memory.



Field logbooks will be bound field survey books or notebooks. Logbooks will be assigned to field personnel and will be stored in CRA's Indianapolis, IN office when not in use. Each logbook will be identified by the project number (39611).

The title page of each logbook will contain the following:

- person to whom or task for which the logbook is assigned;
- project number;
- project name;
- the starting date for entries into the logbook; and
- the ending date for entries into the logbook.

Entries into the logbook will contain a variety of information. At the beginning of each day's logbook entry, the date, start time, weather, names of all sampling team members present, and the signature of the person making the entry will be entered. The names of individuals visiting the Site or field sampling team and the purpose of their visit will also be recorded in the field logbook.

All field measurements taken and samples collected will be recorded. All logbook entries will be recorded in ink, signed and dated. If an incorrect logbook entry is made, the incorrect information will be crossed out with a single strike mark, which is initialed and dated by the person making the erroneous entry. The correct information will be entered into the logbook adjacent to the original entry.

Whenever a sample is collected or a measurement is made, a detailed description of the location will be recorded in the logbook. Photographs taken at a location, if any, will also be noted in the logbook. All equipment used to obtain field measurements will be recorded in the field logbook. The sample numbering system (as described in Section 4.1) will be recorded in the field logbook correlating the unique sample number to the sample location and sample depth (if necessary). In addition, the calibration data for all field measurement equipment will be recorded in the field logbook.

Samples will be collected following the sampling procedures documented in the FSP. The equipment used to collect samples, time of sample collection, sample description, and volume and number of containers will be recorded in the field logbook.

#### 4.2.3 TRANSFER OF CUSTODY AND SHIPMENT PROCEDURES

The sample packaging and shipping procedures summarized below will ensure that the samples arrive at the laboratory with the chain-of-custody intact.

1. The field sampler is personally responsible for the care and custody of the samples until they are transferred to another person or the laboratory. As few people as possible will handle the samples.
2. All sample containers will be identified by using sample labels which include the date of collection, unique sample number, and analyses to be performed.
3. Sample labels will be completed for each sample using waterproof ink.
4. Samples will be placed in coolers containing ice immediately after collection.
5. Samples will be accompanied by a properly completed chain-of-custody form. An example chain of custody form is included as Figure 4.2. The sample identification numbers will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving the samples will sign and record the date and time on the form. The chain-of-custody form documents sample custody transfers from the sampler to another person, to the laboratory, or to/from a secure storage area.
6. All sample shipments will be accompanied by the chain-of-custody form identifying its contents. The chain-of-custody form is a three- or four-part carbonless-copy form. The form is completed by the sampling team and, after signing and relinquishing custody to the shipper, retains the bottom copy. The shipper, if different than the sampling team members, retains one of the middle (typically pink) copies after relinquishing custody to the laboratory. Either the yellow copy or a photocopy of the top copy is retained by the laboratory and the fully executed top copy is returned as part of the data deliverables package.
7. Samples will be properly packaged for shipment (see Table 4.1) and dispatched to the appropriate laboratory for analysis with a separate signed chain-of-custody form enclosed in and secured to the inside top of each shipping cooler. Shipping coolers will be secured with custody tape for shipment to the laboratory. The custody tape is then covered with clear plastic tape to prevent accidental damage to the custody tape.
8. If the samples are sent by common carrier, a bill of lading will be used and copies will be retained as permanent documentation. Commercial carriers are not required to sign the chain of custody form as long as the form is sealed inside the sample cooler and the custody tape remains intact.

9. If samples are not shipped to the laboratory the same day the samples are collected in the field, additional ice will be placed in the coolers, the coolers will be sealed and kept in a designated secure area until they are shipped to the laboratory as described above.

#### **4.3 LABORATORY CHAIN-OF-CUSTODY PROCEDURES**

Laboratory sample custody begins when the samples are received at the laboratory. The laboratory's sample custodian will assign a unique laboratory sample identification number to each incoming sample. The field sample identification numbers, laboratory sample identification numbers, date and time of sample collection, date and time of sample receipt, and requested analyses will be entered into the sample receiving log. The laboratory's sample log-in, custody, and document control procedures are detailed in the appropriate SOPs in the QAPP (Attachment B of the RD Work Plan).

#### **4.4 LABORATORY STORAGE OF SAMPLES**

Following log-in, all samples will be stored within an access-controlled location and will be maintained properly preserved (as defined in Table 4.1) until completion of all laboratory analyses. Unused sample aliquots and sample extracts/digestates/distillates will be maintained properly preserved for a minimum of 30 days following receipt of the final report by CRA. The laboratory will be responsible for the disposal of unused sample aliquots, samples, containers, and sample extracts/digestates/distillates in accordance with all applicable local, state, and federal regulations.

The laboratory will be responsible for maintaining analytical log books and laboratory data. Raw laboratory data files will be inventoried and maintained by the laboratory for a minimum period of 7 years, after which time CRA will advise the laboratory regarding additional storage.

#### **4.5 FINAL EVIDENCE FILES CUSTODY PROCEDURES**

Evidential files for the entire project will be maintained by CRA and will consist of the following:

1. project plan;
2. project log books;

3. field data records;
4. sample identification documents;
5. chain of custody records;
6. correspondence;
7. references, literature;
8. final laboratory reports;
9. miscellaneous - photos, maps, drawings, etc.; and
10. final report.

The final evidence file materials will be the responsibility of the evidentiary file custodian (CRA's Project Manager) with respect to maintenance and document removal. Section XIV of the ASAO specifies that all records be maintained for a minimum of 10 years after commencement of construction of any remedial action. USEPA is to be notified at least 90 days before the documents are scheduled to be destroyed. All records for the RD will be maintained consistent with the requirements of the ASAO.

## 5.0 FIELD CALIBRATION, PREVENTATIVE MAINTENANCE, AND STANDARD OPERATING PROCEDURES

### 5.1 PHOTOIONIZATION DETECTOR (PID)

The PID(s) will be maintained and used according to the manufacturer's specifications. The operating manual is kept in the instrument case. Field calibration, including date, time, standard used, results, and corrective actions taken will be recorded in the field logbook. The PID will be calibrated at least once daily, prior to use. Recalibration will be undertaken at more frequent intervals if there is any indication of faulty performance. Calibration check results must be  $\pm 10$  percent of the true value. If the result is outside of  $\pm 10$  percent, the meter will be recalibrated. Field calibration will be carried out according to the manufacturer's procedure. All initial and continuing PID calibrations performed in the field will be carried out using two reference standards.

The SOP for conducting headspace readings using the PID is in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

### 5.2 FLAME IONIZATION/PID DUAL DETECTOR

The FID/PID(s) will be maintained and used according to the manufacturer's specifications. The operating manual is kept in the instrument case. Field calibration, including date, time, standard used, results, and corrective actions taken will be recorded in the field logbook. The FID/PID will be calibrated at least once daily, prior to use. Recalibration will be undertaken at more frequent intervals if there is any indication of faulty performance. Calibration check results must be  $\pm 10$  percent of the true value. If the result is outside of  $\pm 10$  percent, the meter will be recalibrated. Field calibration will be carried out according to the manufacturer's procedure. All initial and continuing FID/PID calibrations performed in the field will be carried out using two reference standards.

The SOP for conducting readings using the FID/PID is in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

### 5.3 pH, TEMPERATURE, ORP, AND CONDUCTIVITY INSTRUMENT

pH, temperature, conductivity, and ORP will be measured using a YSI Model 3560 instrument, or equivalent. The instrument will be calibrated daily, or as necessary, if

malfunction is suspected. Initial calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

#### **5.4      TURBIDITY INSTRUMENT**

Turbidity will be measured using an HF Scientific DRT-15C Turbidimeter, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Initial calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

#### **5.5      DISSOLVED OXYGEN INSTRUMENT**

Dissolved oxygen will be measured using a YSI Model 52 instrument, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Calibration will be performed in accordance with manufacturer's requirements. The standard operating procedures are in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

#### **5.6      WATER LEVEL INDICATOR**

Water level measurements will be collected using a Solinst Model 101 water level indicator, or equivalent. The instruments do not require field calibration. The only field maintenance required is battery replacement.

Water level meters are calibrated against a primary standard (steel tape or chain) once every year. The calibration records for all water level meters will be maintained in a field file and be available for review upon request.

#### **5.7      LANDFILL GAS METER**

Landfill gas measurements will be collected using a Landtec Gas Extraction Monitor, GEM-500 meter indicator, or equivalent. The instrument will be calibrated daily, or as necessary, if malfunction is suspected. Calibration will be performed in accordance with

manufacturer's requirements. The standard operating procedures are in Attachment B. Table 3.1 summarizes calibration check frequency and control limits.

## 5.8 DIGITAL MANOMETER

A digital manometer (Dwyer) is a battery powered, hand held, digital pressure indicator used for measurement of positive, negative, or differential pressure. The instrument uses a pressure transducer to measure the pressure at the inlet port. The instrument can measure positive or negative pressures as low as 0.01 inch of water column (in. W.C.). A typical range of the instrument is 0 to 20 in. W.C., however, a wide variety of ranges and accuracy are available. As these instruments are often more sensitive than other pressure gages, care must be taken in interpreting unsteady readings. Performance of these instruments may be affected by cold. Generally, calibration consists of zeroing the instrument before each measurement.

## 6.0 EQUIPMENT CLEANING PROCEDURES

### 6.1 SAMPLING EQUIPMENT DECONTAMINATION PROCEDURES

Stainless steel split-spoon soil samplers and VAS tools used for the collection of samples for chemical analysis will be cleaned prior to use and between each sampling point in accordance with the following procedure:

- brush with soapy (phosphate-free soap) water;
- rinse with potable water; and
- rinse with distilled water.

The water level indicator, water level plover, surge block, slug, and dissolved oxygen electrode and cable will be cleaned prior to use and between each sampling point by the following procedure:

- sprays of potable or distilled water on the outside surfaces; and
- wipe outside surface with paper towel.

The submersible pump used for well development and groundwater purging and sampling will be decontaminated prior to use and between each location according to the following procedures:

- Wash - spray the reel, and pump with potable water to rinse off particulates;
- Rinse - circulate potable water through the pump until all traces of soap are gone;
- Final Rinse - Operate pump in the basin with distilled or de-ionized water and pump out 1 to 2 gallons; and
- Wrap - The pump will be wrapped in aluminum foil for storage or transport.

The tubing will be dedicated to each well and either left hanging within the well for reuse or disposed of after sampling of each well is completed.

### 6.2 DRILLING EQUIPMENT DECONTAMINATION PROCEDURES

The drill rig, augers, split-spoon samplers, rotasonic core barrels and casings, and drill rods will be steam-cleaned before startup of field operations and after each boring using a high-pressure, high-temperature, hot water cleaner. The potable water used will come



from an off-Site source free of contamination (a fire hydrant may be used). One sample of potable water will be analyzed for VOCs to verify water quality. In the event that the potable water source is changed, a sample will be collected from the new source.

Split-spoon samplers will be washed before each sample is collected using a brush and non-phosphate laboratory-grade detergent, such as Alconox<sup>®</sup>, rinsed with potable water, and rinsed again with distilled water.

## 7.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE (IDW)

The IDW materials that are expected to be produced during the field activities include drill cuttings, development and purge water from monitoring wells, decontamination water, used personal protective equipment (PPE), and used disposable sampling equipment. Each of these waste streams will be managed as discussed below.

CRA will store drill cuttings in drums, containers, or in covered stockpiles pending final disposal at the Site. CRA will either dispose of the cuttings off Site or spread the cuttings on the ground and cover with clean soil as part of landfill cover repair activities.

Development and purge water from monitoring wells and decontamination water will be contained temporarily adjacent to the monitoring well location where the water was generated. Once development and sampling activities are complete, the water will be disposed of either on the ground on Site or disposed of off Site.

Used PPE and used disposable sampling equipment will be placed in garbage bags and stored within a designated area of the Site. The material will then be disposed of at a sanitary landfill.

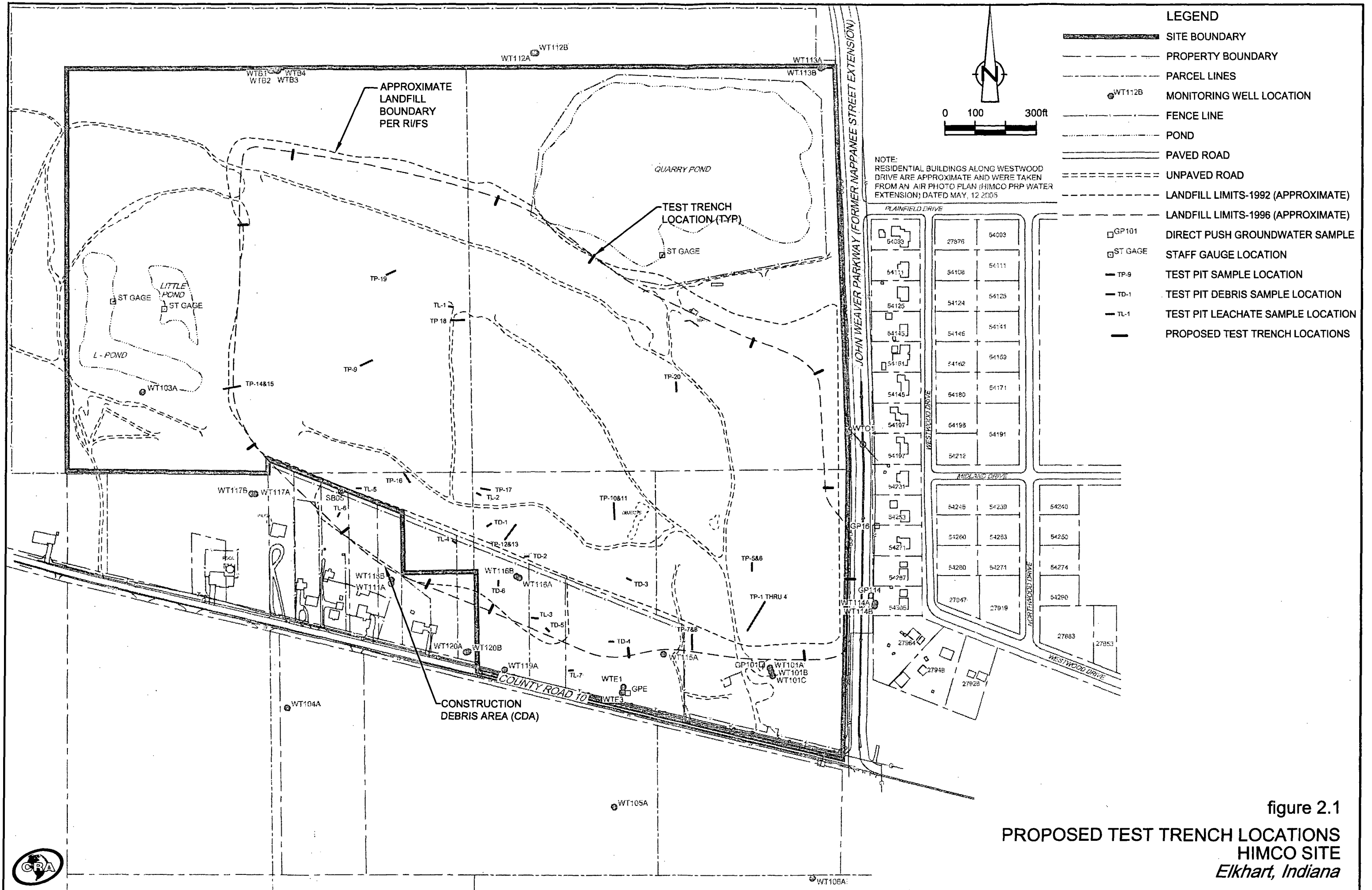
Decontamination water will be contained temporarily and then transferred to a labeled drum or waste water storage tank at the Site. The decontamination water will be characterized and disposed of off Site at the conclusion of the investigative activities.

## 8.0 REFERENCES

Ohio Environmental Protection Agency, February 1995. Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring.

United States Environmental Protection Agency, August 1991. NEIC Policies and Procedures, EPA-330/9-78-0001-R.





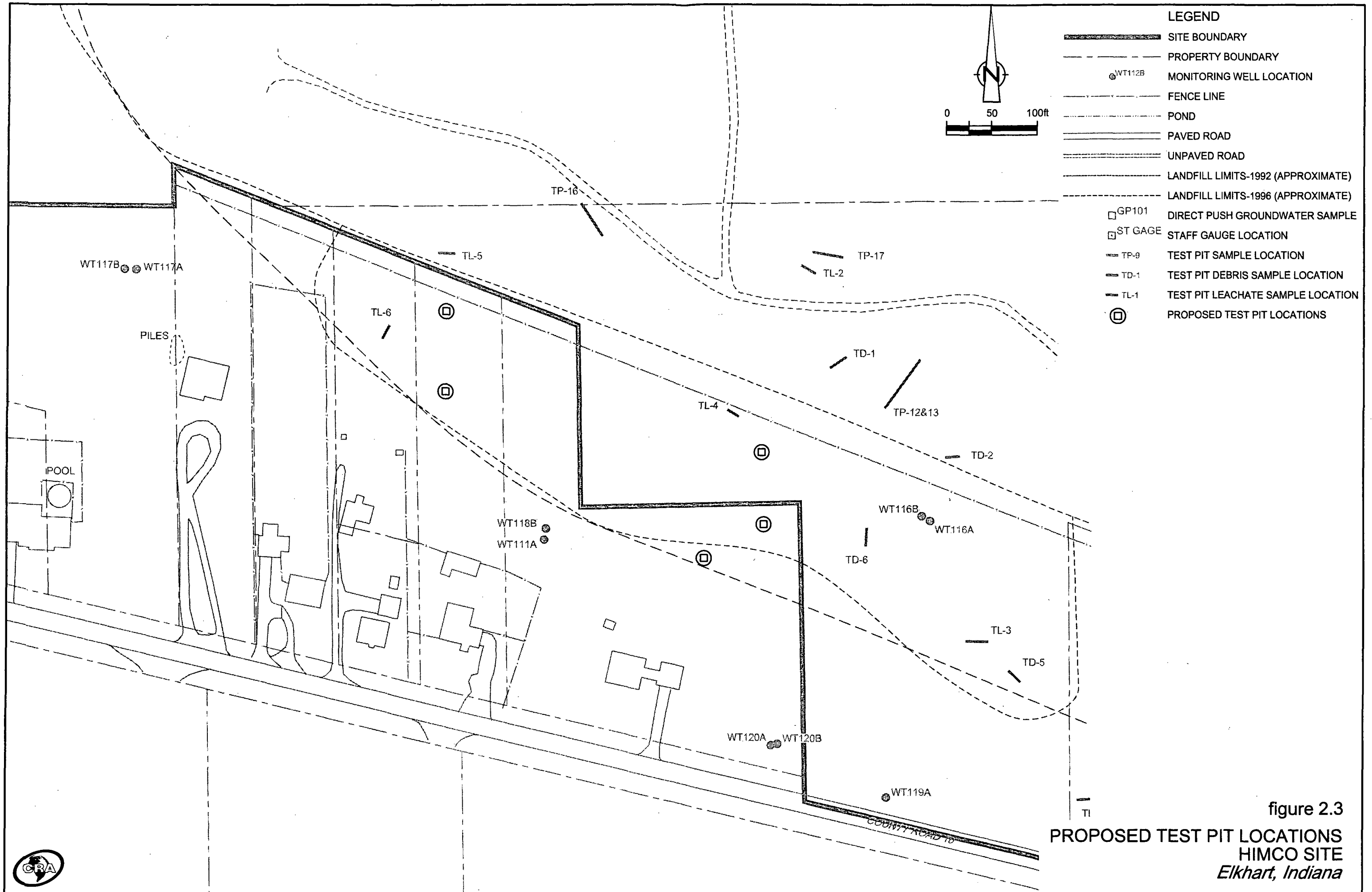
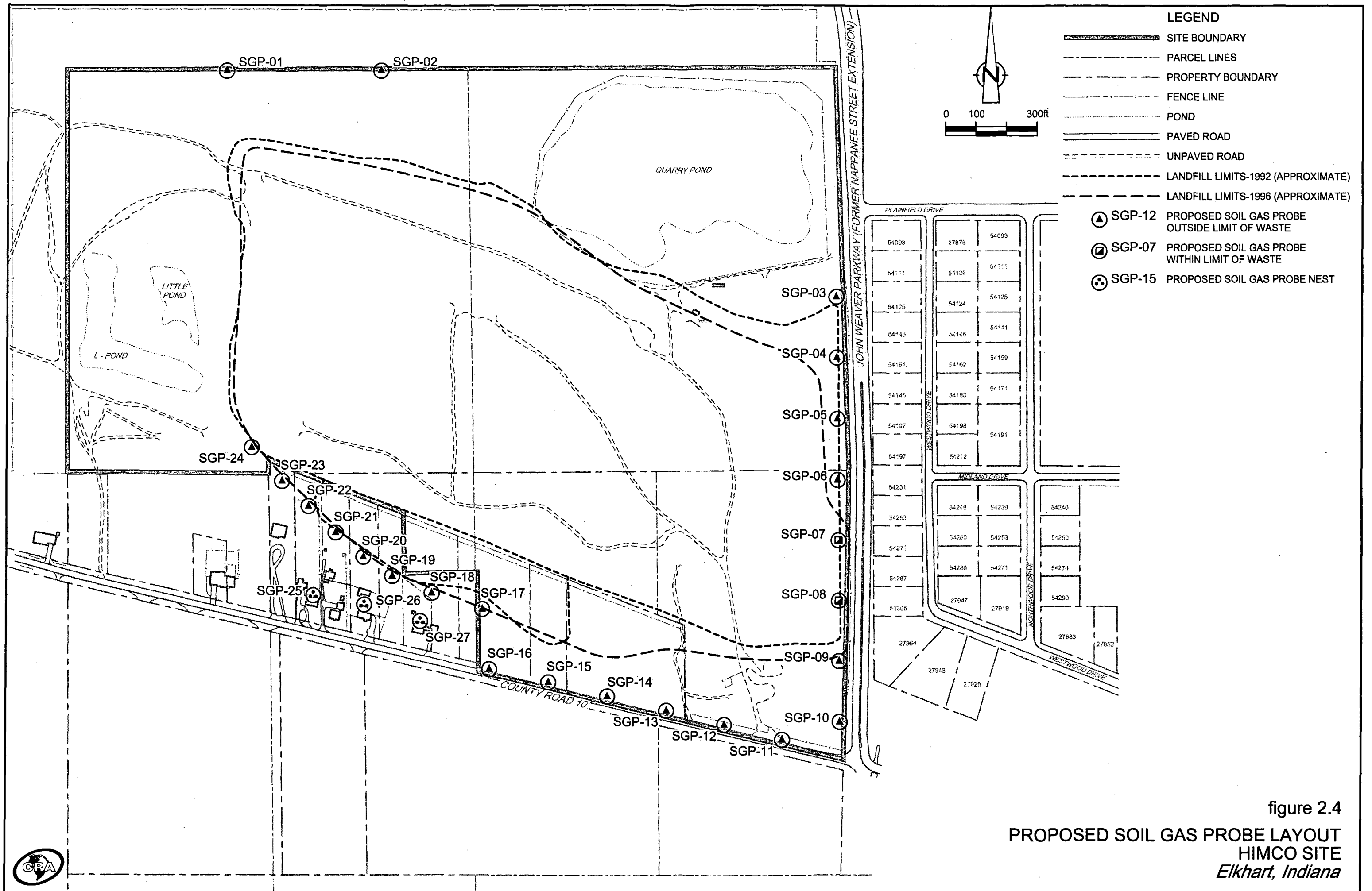


figure 2.3  
**PROPOSED TEST PIT LOCATIONS**  
**HIMCO SITE**  
*Elkhart, Indiana*





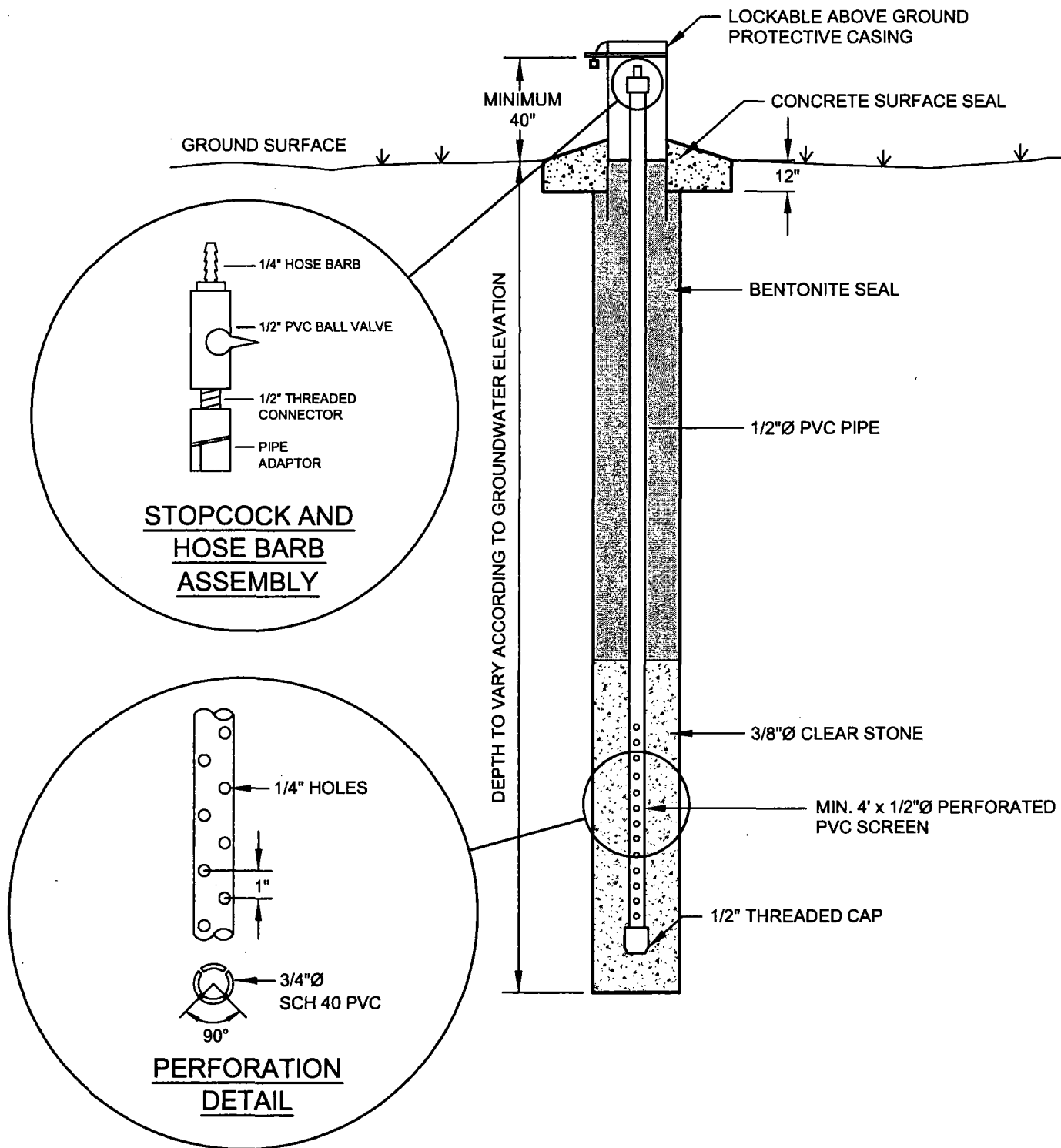


figure 2.5  
TYPICAL SOIL GAS PROBE  
HIMCO SITE  
*Elkhart, Indiana*



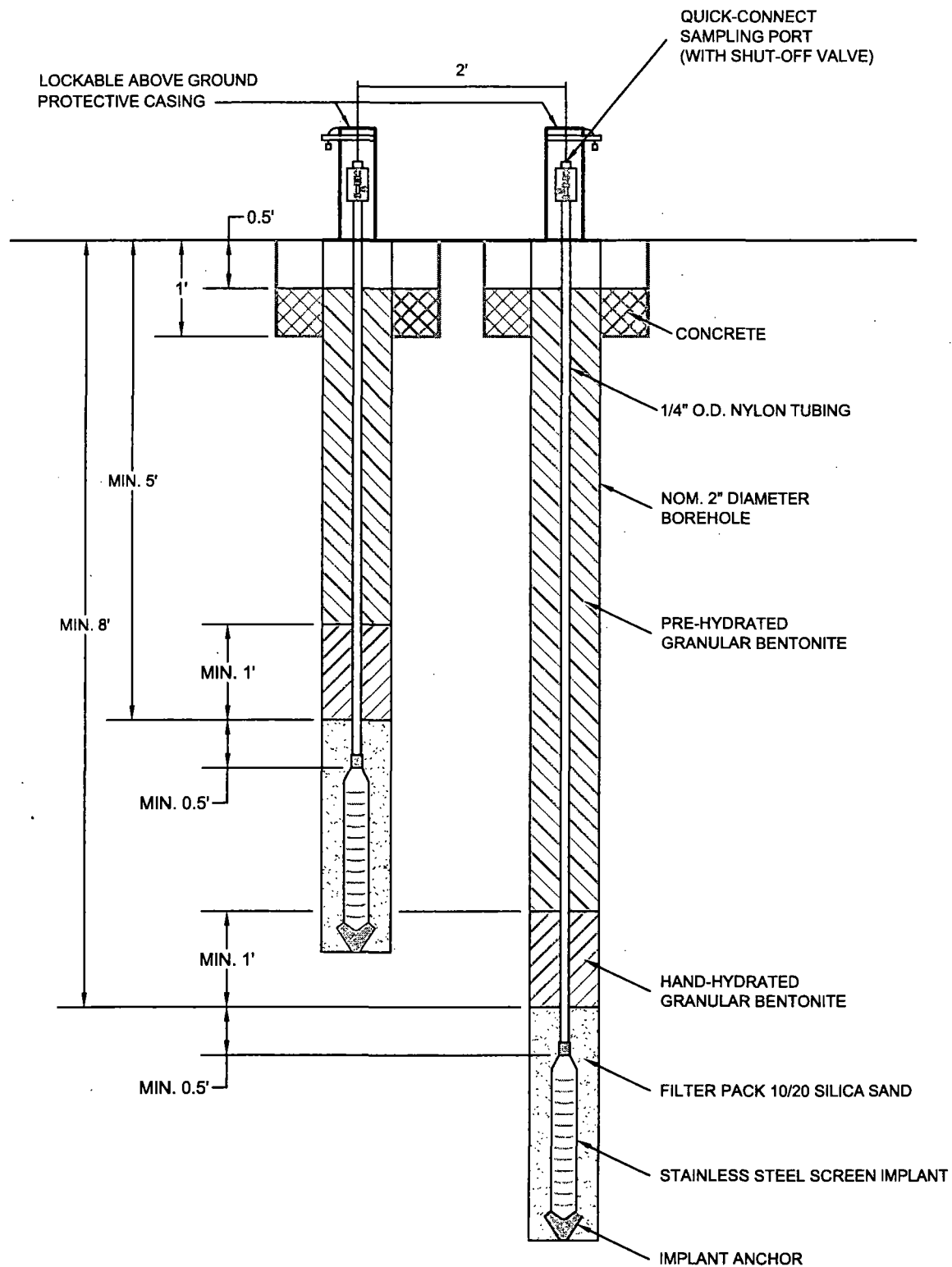


figure 2.6  
TYPICAL SOIL GAS PROBE NEST  
HIMCO SITE  
*Elkhart, Indiana*



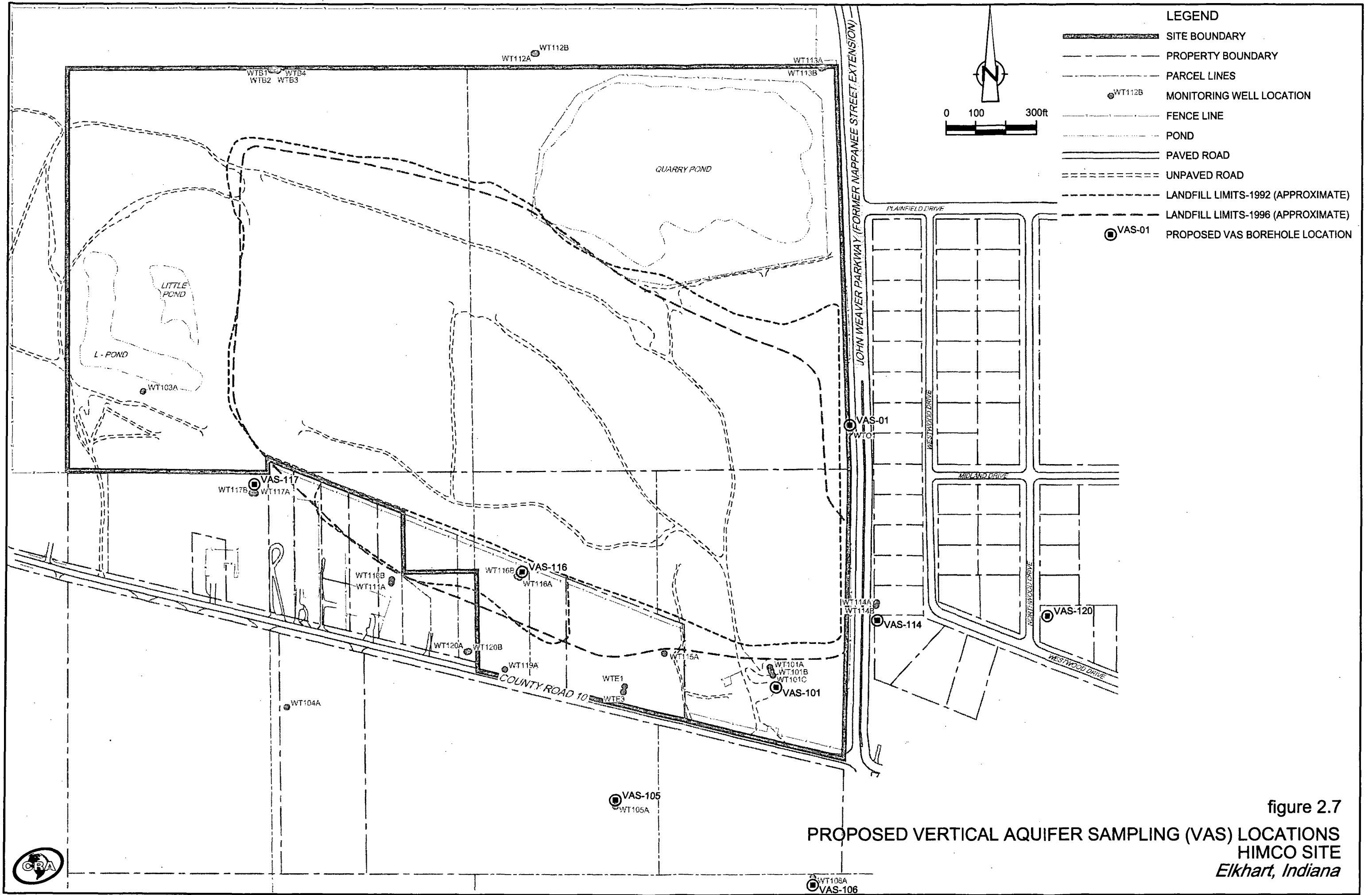


figure 2.7  
 PROPOSED VERTICAL AQUIFER SAMPLING (VAS) LOCATIONS  
 HIMCO SITE  
 Elkhart, Indiana

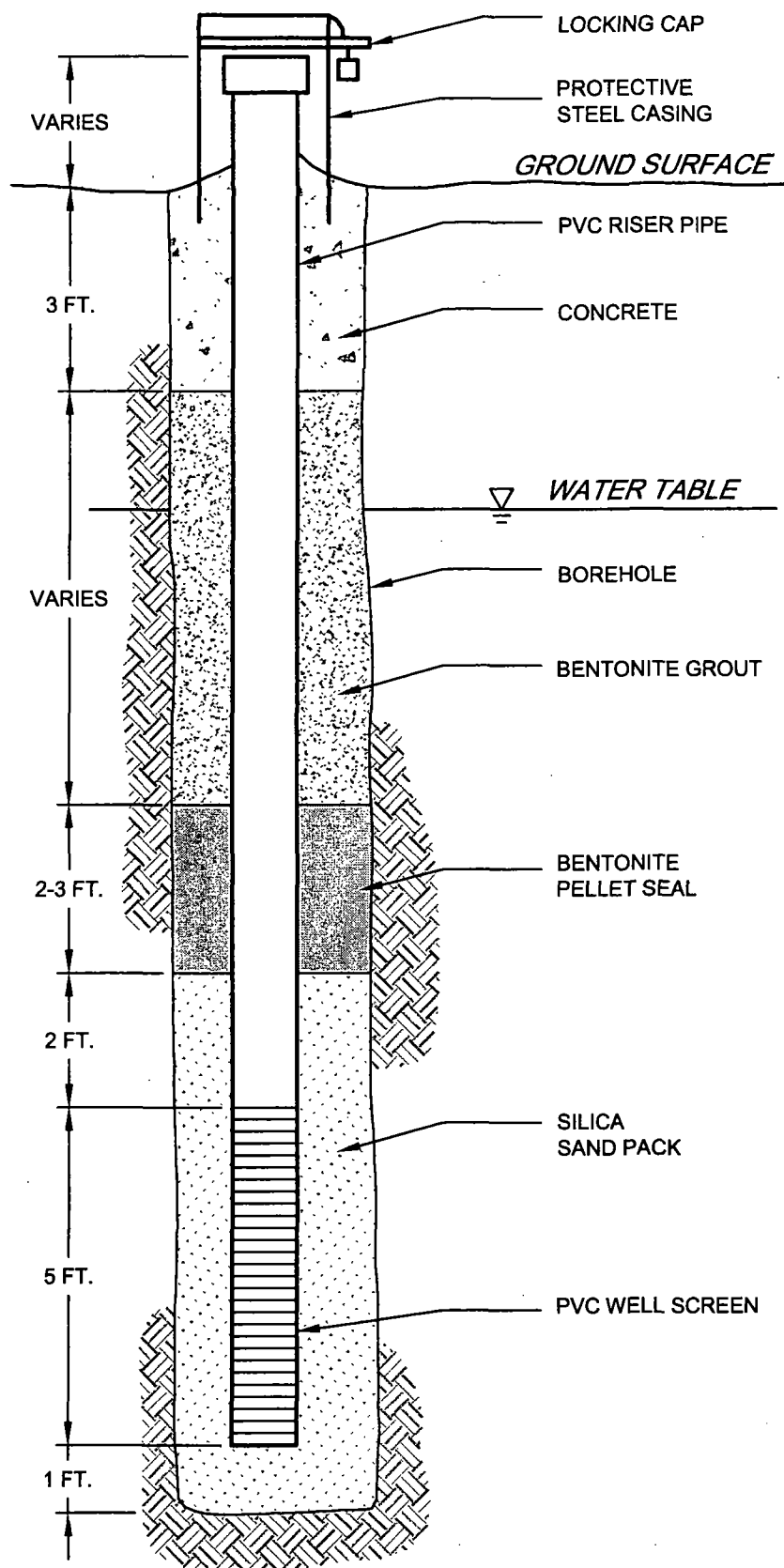
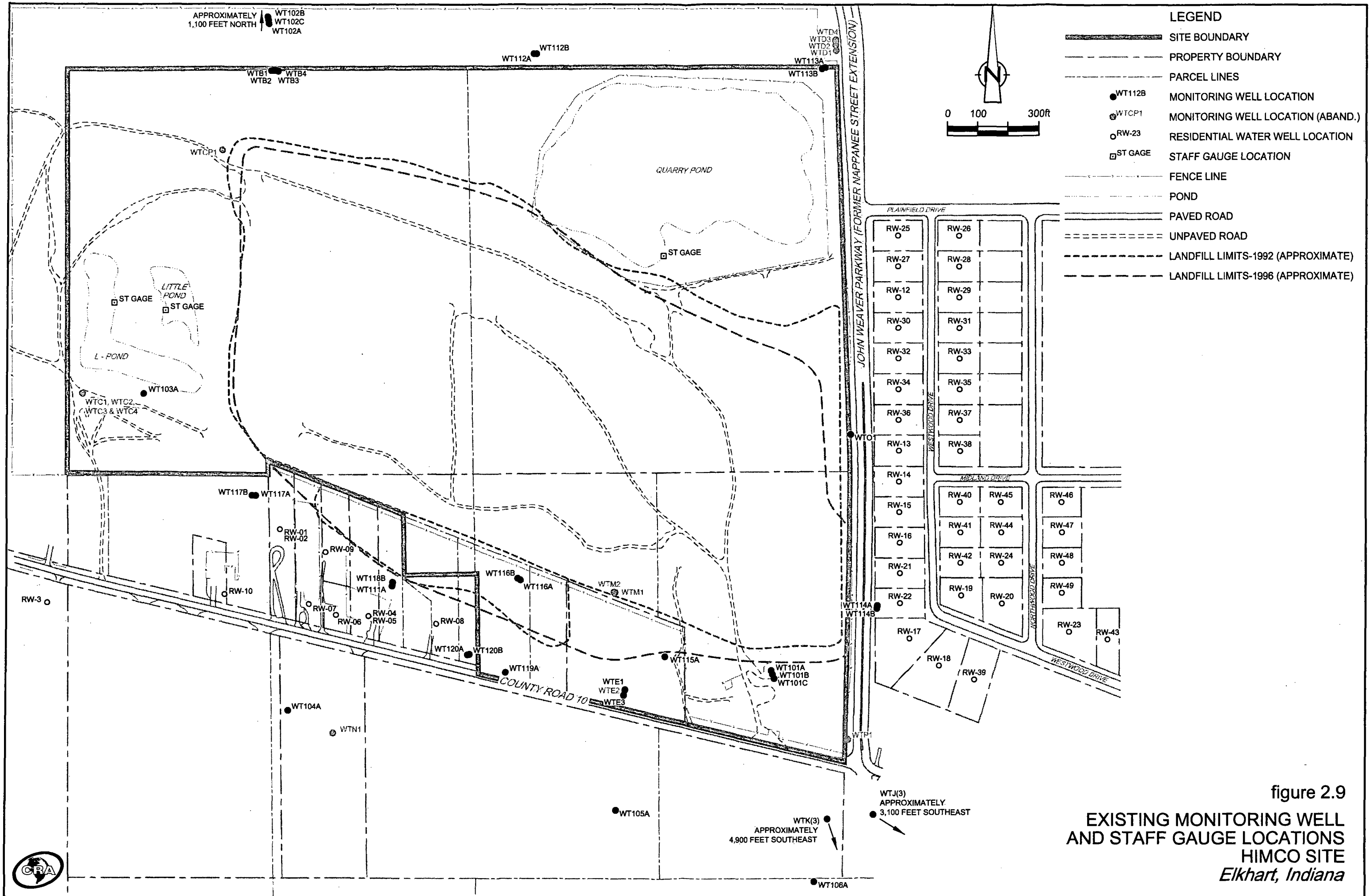


figure 2.8

TYPICAL OVERBURDEN MONITORING WELL  
HIMCO SITE  
Elkhart, Indiana





JOB NUMBER

DAY/MONTH/YEAR

A 1886 WDG -07/11/94-AB

SERIES

SAMPLER'S  
INITIALS

SAMPLE IDENTIFICATION  
DESIGNATION

figure 4.1

TYPICAL SAMPLE LABEL  
HIMCO SITE  
*Elkhart, Indiana*



Service Requested:	X	Regular (default) (5 working days)
Date Required:		Priority (50% surcharge) (2-3 working days)
		Emergency (100% surcharge) (1-2 working days)

[illegible]

PINK - Customer Copy

TYPICAL COMPLETED CHAIN OF CUSTODY FORM  
HIMCO SITE  
*Elkhart, Indiana*





TABLE 2.1  
SUMMARY OF SAMPLING AND ANALYSIS PROGRAM  
HIMCO SITE  
ELKHART, INDIANA

Location/Task	Sample Matrix	Field Parameters	Laboratory Parameters <sup>2</sup>	Approximate Number of Samples	QC Samples <sup>1</sup>			Total
					Field Blanks	Field Duplicates	MS/MSD <sup>3</sup>	
Test Pit Sampling	Soil	PID screening	TCL SVOCs, TAL Metals, Total cyanide.	15	1	1	1	18
Landfill Cover Soil Borings	Soil	PID screening	Grain size distribution, pH, organic content, NPK content	27	0	0	0	27
Soil Gas Probe Installation (single probes)	Soil	FID/PID screening, water level, gas pressure, methane, oxygen, carbon dioxide	TCL VOCs	TBD <sup>4</sup>	0	1 per 20	1 per 20	TBD
Soil Gas Probe Nests Installation (each nested pair)	Soil	FID/PID screening	None	24	0	0	0	24
Vertical Aquifer Sampling	Groundwater	None	Grain size distribution, porosity/water-filled porosity, dry bulk density, vapor permeability, fraction of organic carbon	6	0	0	0	6
Groundwater Sampling	Groundwater	pH, DO, temperature, conductivity, ORP, turbidity, water level	TCL VOCs, TAL Metals, bromide, sulfate, chloride	126	7	7	7	147
Soil Gas Sampling	Gas	FID/PID screening, water level, gas pressure, methane, oxygen, carbon dioxide	TCL VOCs, TCL SVOCs, TAL Metals, bromide, sulfate, chloride	39 <sup>5</sup>	2	2	2	45
			VOCs, nitrogen, hydrogen sulfide, carbon monoxide, NMOC	31	0	2	1	34

## Notes:

<sup>1</sup> One trip blank sample will be included in each cooler containing groundwater samples for VOC analysis.

<sup>2</sup> TCL - Target Compound List (TCL), SVOCs - Semivolatile Organic Compounds (SVOCs), TAL - Target Analyte List, VOCs - Volatile Organic Compounds, NMOC - Non-Methane Organic Compounds, NPK - Nitrogen, Phosphorus, Potassium.

<sup>3</sup> Matrix spike/matrix duplicate (MS/MSD) analyses will be performed for organic analyses. MS/MSD samples will be collected with extra sample volume for water samples, at a frequency of 1 per 20 or fewer investigative samples. Triple the normal sample volume will be collected for VOCs and double the normal volume for SVOCs. No additional sample volume is required for inorganic analyses. Duplicate laboratory control samples (LCS/LCSD) will be analyzed at a frequency of 1 per 20 or fewer soil gas samples.

<sup>4</sup> To be determined based on headspace PID screening. A soil sample will be collected for VOC analysis if headspace PID reading is greater than 10 ppm above background PID readings.

<sup>5</sup> Number based on baseline monitoring of 39 wells to be monitored quarterly for 2 years.



TABLE 3.1  
FIELD INSTRUMENT CALIBRATION AND QA SUMMARY  
HIMCO SITE  
ELKHART, INDIANA

Instrument (1) (Analysis)	Method Reference	# Standards Initial Calibration	Acceptance/ Rejection Criteria - Initial Calibration	Frequency of Calibration	Frequency of Initial Calibration Verification	Acceptance/ Rejection Criteria- Initial Calibration Verification	Frequency of Continuing Calibration Verification	Acceptance/ Rejection Criteria- Continuing Calibration Verification	Other Calibration Requirements	Required Field QA/QC
YSI 3560 Water Quality Meter (pH, Temperature)	EPA 150.1	2	pH 7.00 buffer ± 0.1 SU	At least daily, or as required (when CCV fails acceptance criteria)	As needed	Same as ICV	Every 10 samples	Same as ICV	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 0.2 SU of original.
(Conductivity)	EPA 120.1	NA	NA	Factory-calibrated	Daily	1,000 ± 0.70 mmho	Every 10 samples	1,000 ± 0.70 mmho	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 15% of original.
(ORP)	SM 2580 B	1	NA (ZoBell Solution Cal.)	At least daily, or as required (when CCV fails acceptance criteria)	As needed	± 10 mV	Every 10 samples	Same as ICV	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 10 mV of original.
YSI 52 (Dissolved Oxygen)	EPA 360.1	1	NA (moist air calibration)	At least daily, or as required (when CCV fails acceptance criteria)	As needed	± 10 %	Every 10 samples	Same as ICV	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 15% of original.
DRT-15C (Turbidity)	NA	NA	Factory-Calibrated	Daily	NA	± 10 %	Every 10	Same as ICV	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 15% of original.
MiniRae Classic PID (Organic Vapors)	NA	2	Instrument-Determined	Daily	NA	NA	Every 10 samples	± 10 %	None	None
Landtec Gas Extraction Monitor (Landfill Gas)	NA	1	Factory-Calibrated	Daily	As needed	± 10 %	Every 10	Same as ICV	None	Duplicate 1 of every 10 samples. (2) Duplicate must be ± 15% of original.

Notes:  
(1) Equivalent instruments to those specified may also be used.  
(2) If less than 10 samples are analyzed, a duplicate is still required.  
ICV Initial Calibration verification.  
CCV Continuing Calibration verification.  
SU Standard pH units.

TABLE 4.1

CONTAINER, PRESERVATION, SHIPPING AND PACKAGING REQUIREMENTS  
HIMCO SITE  
ELKHART, INDIANA

<i>Matrix</i>	<i>Analyses</i>	<i>Sample Containers<sup>1</sup></i>	<i>Preservation<sup>2</sup></i>	<i>Maximum Holding Time from Sample Collection<sup>3</sup></i>	<i>Volume of Sample</i>	<i>Shipping</i>	<i>Normal Packaging</i>
<i>Groundwater</i>							
	TCL VOCs, Dissolved Gases	Three 40-mL septum top vials per analysis	Iced HCl to pH<2	14 days for analysis	Fill completely	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TCL SVOCs	Two 1-L amber glass bottles	Iced	7 days for extraction 40 days after extraction for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TAL Metals	One 1-L polyethylene bottle	HNO <sub>3</sub> to pH<2	6 months for analysis (mercury - 28 days)	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Chloride, Sulfate, Bromide	One 1-L polyethylene bottle	Iced	28 days for analysis	Fill to neck of bottle	Federal Express Priority 1	Bubble Wrap or Foam Chips
<i>Soil</i>							
	TCL SVOCs	One 500-mL glass jar	Iced	14 days for extraction 40 days after extraction for analysis	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips
	TAL Inorganics	One 500-mL glass jar	Iced	6 months for analysis (mercury - 28 days) (cyanide - 14 days)	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips
	Geotechnical	Two 500-mL glass jars	None	None	Fill to shoulder of jar	Federal Express Priority 1	Bubble Wrap or Foam Chips
<i>Soil Gas</i>							
	VOCs, nitrogen, hydrogen sulphide, carbon monoxide, and NMOC	6-liter evacuated canister	None	30 days from collection to completion of analysis	minimum residual negative pressure of 1 to 5 inches of Hg	Federal Express Priority 1	Bubble Wrap or Foam Chips

## Notes:

<sup>1</sup> Where possible, analyses will be combined into the minimum number of sample containers with respect to sample preservation requirements.

<sup>2</sup> Samples requiring refrigeration will be shipped in coolers containing bagged, cubed ice. Following laboratory receipt and log-in, these samples will be stored at 4° ± 2°C.

<sup>3</sup> Maximum holding times presented are technical holding times and are based on the time elapsed from sample collection.



ATTACHMENT A

STANDARD FORMS

[illegible]

# WELL PURGING FIELD INFORMATION FORM

SITE/PROJECT NAME: \_\_\_\_\_

JOB# \_\_\_\_\_

WELL# \_\_\_\_\_

## WELL PURGING INFORMATION

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|

PURGE DATE  
(MM DD YY)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|

SAMPLE DATE  
(MM DD YY)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|

WATER VOL. IN CASING  
(LITRES/GALLONS)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_|

ACTUAL VOLUME PURGED  
(LITRES/GALLONS)

## PURGING AND SAMPLING EQUIPMENT

PURGING EQUIPMENT.....DEDICATED Y N

SAMPLING EQUIPMENT.....DEDICATED Y N

(CIRCLE ONE)

(CIRCLE ONE)

PURGING DEVICE ☐ A - SUBMERSIBLE PUMP D - GAS LIFT PUMP G - BAILER X- \_\_\_\_\_

B - PERISTALTIC PUMP

E - PURGE PUMP

H - WATERRA®

PURGING OTHER (SPECIFY)

SAMPLING DEVICE ☐ C - BLADDER PUMP F - DIPPER BOTTLE X- \_\_\_\_\_

SAMPLING OTHER (SPECIFY)

PURGING DEVICE ☐ A - TEFLON D - PVC X- \_\_\_\_\_

B - STAINLESS STEEL

E - POLYETHYLENE

PURGING OTHER (SPECIFY)

SAMPLING DEVICE ☐ C - POLYPROPYLENE X- \_\_\_\_\_

SAMPLING OTHER (SPECIFY)

PURGING DEVICE ☐ A - TEFLON D - POLYPROPYLENE F - SILICONE X- \_\_\_\_\_

B - TYGON

E - POLYETHYLENE

G - COMBINATION

PURGING OTHER (SPECIFY)

SAMPLING DEVICE ☐ C - ROPE X- \_\_\_\_\_

TEFLON/POLYPROPYLENE

SAMPLING OTHER (SPECIFY)

(SPECIFY)

FILTERING DEVICES 0.45 ☐ A - IN-LINE DISPOSABLE B - PRESSURE C - VACUUM

## FIELD MEASUREMENTS

WELL ELEVATION \_\_\_\_\_ (m/ft)

GROUNDWATER ELEVATION \_\_\_\_\_ (m/ft)

DEPTH TO WATER \_\_\_\_\_ (m/ft)

WELL DEPTH \_\_\_\_\_ (m/ft)

pH

TURBIDITY

CONDUCTIVITY

SAMPLE TEMPERATURE

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (std)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (ntu)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (µm/cm)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (°C)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (std)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (ntu)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (µm/cm)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (°C)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (std)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (ntu)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (µm/cm)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (°C)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (std)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (ntu)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (µm/cm)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (°C)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (std)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (ntu)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (µm/cm)

\_\_\_\_\_|\_\_\_\_\_|\_\_\_\_\_| (°C)

## FIELD COMMENTS

SAMPLE APPEARANCE: \_\_\_\_\_ ODOR: \_\_\_\_\_ COLOR: \_\_\_\_\_ TURBIDITY: \_\_\_\_\_

WEATHER CONDITIONS: WIND SPEED \_\_\_\_\_ DIRECTION \_\_\_\_\_ PRECIPITATION Y/N OUTLOOK \_\_\_\_\_

SPECIFIC COMMENTS \_\_\_\_\_

I CERTIFY THAT SAMPLING PROCEDURES WERE IN ACCORDANCE WITH APPLICABLE CRA PROTOCOLS

CRA

DATE

PRINT

SIGNATURE

PAGE \_\_\_\_ OF \_\_\_\_

HOLE DESIGNATION \_\_\_\_\_  
DATE/TIME STARTED \_\_\_\_\_  
DATE/TIME COMPLETED \_\_\_\_\_  
DRILLING METHOD \_\_\_\_\_  
CRA SUPERVISOR \_\_\_\_\_

01001-00(029)GN-WA023 SEP 13/99 (SP-17) REVISION 3





ATTACHMENT B

FIELD STANDARD OPERATING PROCEDURES

## DISSOLVED OXYGEN

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Methods for Chemical Analysis of Water and Wastes":  
EPA-600/4-79-020, revised March 1983, Method 360.1

Sensitivity: 0.1 mg/L as O<sub>2</sub>

Optimum Range: 0.1 mg/L to 20 mg/L O<sub>2</sub>

Sample Handling: Determined on site

Reagents and Apparatus:

1. Temperature compensated dissolved oxygen (DO) meter, YSI Model 52;
2. DO probe, YSI 5739 Field Probe;
3. DO probe electrolyte solution;
4. DO membrane replacement kit; and
5. Distilled water in wash bottle.

Setting Up DO Sensor:

The sensor is shipped dry and must be filled before use.

1. Unscrew sensor guard, remove o-ring and membrane, and rinse with distilled water.
2. Holding probe in left hand, successively fill the sensor body with electrolyte while pumping the diaphragm with a soft, blunt tool (e.g., pencil eraser). Continue filling and pumping until no more air bubbles appear. Add electrolyte until a large meniscus completely covers the gold cathode.
3. In a single, continuous motion, stretch membrane up, over, and down the sensor. Secure other end of membrane with forefinger.
4. Roll o-ring over probe (do not touch membrane) and trim off excess membrane using scissors or sharp knife.

again. If still outside the control limit, recalibrate the meter and reanalyze all samples analyzed since the last in control calibration.

3. Only distilled water is to be used for probe rinsing prior to analyses.

#### Interferences:

Interferences in DO measurements generally occur due to membrane coating. Clean probe as specified in the sensor manual.

The presence of other gases such as chlorine, nitrous and nitric oxide, hydrogen sulfide and sulfur dioxide interfere with DO measurements. The sulfur based compounds will tarnish the electrodes resulting in sluggish or erratic measurements. Polishing the electrodes as specified in the operating manual will restore the performance of the meter. Recalibrate meter before analysis of next sample.

## GAS EXTRACTION MONITOR

Scope and Application: This method is applicable to screening methane, carbon dioxide, and oxygen content in landfill gas.

Method: Infrared Gas Analyzer

Sensitivity: ±1 percent methane by volume  
±1 percent carbon dioxide  
±1 percent oxygen by volume

Optimum Range: 0 to 100 percent methane  
0 to 100 percent carbon dioxide  
0 to 25 percent oxygen

Sample Handling: Determined on site

Reagents and Apparatus:

1. Landtec Gas Extraction Monitor, GEM-500;
2. Calibration gas (commercially available standard cylinders containing methane, carbon dioxide, oxygen);
3. Calibration apparatus and tubing; and
4. Battery chargers.

Setting Up Gas Extraction Monitor:

1. Ensure the inlet filter is clean by using an Allen key to unscrew the inlet port from the instrument body. Replace inlet filter if needed.
2. Thread the inlet port back into the instrument body and tighten.
3. Check to ensure the sample hose's filter/water trap assembly is clean by disassembling the threaded plastic housing. Replace the filter if needed. Re-thread the plastic housing back together and tighten.

Field Calibration in Procedure:

1. Turn the instrument on by pressing the "Red" button. Press button [0] to exit the MAIN MENU Screen. Press button [1] to enter the GENERAL UTILITIES Screen.
2. Press button [9] for more OPTIONS. Press button [5] for GAS CALIBRATION Screen.

5. Configure GEM-500 so as to measure carbon dioxide concentration and record reading in the field logbook.
6. Disconnect personal pump from sampling port. The sampling train will continue to operate for a period of 1 minute, drawing in ambient air, to purge the train of sample.
7. Repeat steps 1 through 6 for each sample.

Quality Control:

1. Calibration check results must be within 10 percent of the true value. If the result is outside of 10 percent, recalibrate the instrument s specified above. Record the calibration standard in the field logbook.
2. Duplicate samples are not analyzed since the headspace readings will vary considerably as volatilization in the soil occurs.

Interferences:

In the event that the GEM-500 is operating during the winter months, the instrument will be stored and maintained in an ambient temperature operating range between 10°F and 104°F.

## DIGITAL MANOMETER

Scope and Application: This method is applicable to measure the positive, negative or differential pressure within a soil gas probe.

Method: Digital Manometer

Sensitivity: 0-20 inches H<sub>2</sub>O to 0-150 psid  
±0.5 percent accuracy

Sample Handling: Determined on site

Reagents and Apparatus:

1. Dwyer Series 477 Handheld Digital Manometer;
2. Batteries.

Field Calibration in Procedure:

1. Turn the instrument on by pressing the "ON/OFF" button once.
2. To zero the meter before use, vent both ports to atmosphere so no pressure is applied to either port. Press the ZERO/STORE key and ---- will be momentarily displayed as zeroing occurs. Zeroing is not possible when the memory mode is in use.

Pressure Measurement

Pressure measurements should always be taken prior to combustible gas concentration measurement. Sampling combustible gas from the probe will affect the probe pressures. To monitor pressures in the probe, the following procedures are implemented in the following order:

1. The positive lead of the pressure gage is connected to the hose barb on the probe (if supplied). Some sites may require other methods to sample the probe. Discuss this with the Project Coordinator prior to going out in the field. Ensuring a gastight seal is the primary goal. The positive lead ensures that a positive reading on the meter indicates pressure and a negative reading indicates a vacuum. If magnehelic gages are used, the lead may have to be switched to obtain a reading.

*Note: Minimize the number of connections between the sample point and the instrument and ensure they are all gas tight or erroneous readings may result. Care must always be taken to ensure that all connections are snug fitting and leak free prior to recording the reading.*

2. Open the stopcock.

## TURBIDITY

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Nephelometric

Reference: "Methods for Chemical Analysis of Water and Wastes":  
EPA-600/4-79-020, revised March 1983, Method 180.1

Sensitivity: 0.01 Nephelometric Turbidity Unit (NTU)

Optimum Range: 0 - 20; 0 - 200 NTU

Sample Handling: Determined on site

Reagents and Apparatus:

1. Direct reading turbidity meter, HF Scientific Model DRT-15C;
2. Cuvettes with screw tops;
3. Battery charger;
4. 0.02 NTU (nominal) reference standard; and
5. Distilled or deionized water in wash bottle.

Calibration Check and Operation

The turbidimeter has been calibrated by the manufacturer and electronic calibration using freshly prepared formazin standards should only be performed if the electronic printed circuit board, the photodetectors or the light source has been replaced. The calibration procedure is presented in pages 5 and 6 of the operating manual (attached).

The procedures for calibration checks and the operation of the meter follows:

1. For accurate measurements in the low range rotate the cuvettes in the well to obtain the minimum reading. Mark the cuvette with one of the adhesive dots provided with the instrument so that orientation of the cuvette will be identical each time it is placed in the instrument.
2. To operate the turbidimeter, switch to the "20" range and place the Reference Standard (0.02 NTU) in the optical well.
3. With the light shield in place over the well, adjust the Reference Adjust knob to cause the meter to read the reference standard value on the scale. The unit is now ready for use in either range.

## OXIDATION-REDUCTION POTENTIAL (ORP)

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Standard Methods for the Examination of Water and Wastewater", APHA, 18th edition, 1992, Method 2580B.

Sensitivity: 1 mV

Optimum Range: -1,500 to 1,500 mV

Sample Handling: Determined on site

### Reagents and Apparatus:

1. ORP meter, YSI Model 3560 Water Quality Monitor;
2. ORP electrode assembly, YSI Model 3540;
3. Thermilinear thermistor temperature probe, YSI Model 3510;
4. ZoBell Solution, YSI Model 3682; and
5. Distilled or deionized water in wash bottle.

### Calibration:

1. Turn on the YSI 3500 Water Quality Monitor and set the pH function switch to mV.
2. Connect the shorting cap attached to the 3500 to the mV input jack. The display should read  $000 \pm 2$  mV. This indicates that the 3500 electronics are zeroed.
3. Detach the shorting cap and connect the 3540 to the mV input jack. If a pH electrode is not attached to the pH input jack, connect the shorting cap to it.
4. Attach the 3510 to the TEMP input jack.
5. Rinse the 3540 and 3510 with distilled or deionized water, followed by a rinse with a small amount of reconstituted YSI 3682 ZoBell Solution.
6. Half fill a disposable 50 mL sample cup with ZoBell Solution and fully immerse the bulb of the 3540 and the end of the sheath of the 3510. Allow the sensors to equilibrate, and note the reading.



### Interferences:

Interferences in ORP measurements occur when the platinum electrode surface becomes coated. Clean the ORP electrode as follows:

1. Soft coatings should be removed by use of a wash bottle of water or by gently wiping with a soft cloth. Remove the bulb guard if necessary. Be careful not to scratch the platinum.
2. Hard coatings or organic chemicals should be removed by an appropriate chemical solvent, by gently scrubbing with a very fine cleansing powder such as "Softscrub", or by gently polishing with 600 grade wet silicon carbide paper. Wet a piece of the paper with water and gently polish the electrode with a circular twisting motion.

### Note:

After cleaning the platinum surface, soak the electrode for a 8 to 24 hours in 4.0 pH buffer, then recheck it with YSI 3682 ZoBell Solution before further use.

## pH/TEMPERATURE

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Potentiometric

Reference: "Methods for Chemical Analysis of Water and Wastes":  
EPA-600/4-79-020, revised March 1983, Method 150.1

Sensitivity: 0.01 pH unit; 0.1°C

Optimum Range: pH 1.00 to 12.00; temperature -5 to 50°C

Sample Handling: Determined on site

Reagents and Apparatus:

1. Temperature compensated pH meter, YSI Model 3560 Water Quality Monitoring System;
2. Combination pH electrode YSI Model 3530;
3. Thermilinear thermister YSI Model 3510 temperature probe;
4. pH buffer solutions, pH 4.00, 7.00, and 10.00 (certified buffer solutions); and
5. Distilled or deionized water in wash bottle.

Calibration:

1. Switch On/Off key to On. Before connecting the pH electrode, zero the electronics with the shorting cap attached to the meter. Turn on the meter and set the pH function switch to pH. Connect the shorting cap to the pH input jack and set the manual temperature compensation knob to 25°C. Adjust the CAL control to indicate 7.00  $\pm$  0.01 on the pH-mV display. Disconnect the shorting cap from the pH input and connect it to the mV input jack. The monitor is now zeroed.
2. Test the 3530 pH electrode for noise and offset as follows: Rinse the 3530 and the YSI 3510 Temperature Probe with pH 7.00 buffer to remove any contaminants. Connect the 3530 to the pH input jack and the 3510 to the TEMP input jack. Pour pH 7.00 buffer into a 50 mL sample cup then immerse both of the sensors into the buffer at 25.0  $\pm$  0.1°C (use the °C display to confirm the temperature). Allow the sensors to equilibrate. A display value other than 7.00 shows electrode background noise and offset. The 3530 background noise and offset at pH 7.00 should not exceed  $\pm$  0.2 pH units at 25°C. Replace pH probe if background noise exceeds this tolerance.

the problem, clean the electrode and recalibrate. If drift is still apparent, replace electrode.

2. Calibration check results must be  $\pm 0.10$  pH unit of the true value. If the result is outside of  $\pm 0.10$  pH unit, rinse electrodes and check solution again. If still outside the control limit, recalibrate the meter and reanalyze all samples analyzed since the last in-control calibration.
3. All glassware is to be soap and water washed, tap water rinsed and distilled or deionized water rinsed prior to analyses.

Interferences:

Interferences in pH measurements occur with presence of weak organic and inorganic salts and oil and grease. If oil and grease are visible, note in logbook. Clean electrode with soap and water, followed by 10% HCl and deionized water rinse. Recalibrate meter before analysis of next sample.

## CONDUCTIVITY

Scope and Application: This method is applicable to surface water, wastewater and groundwater.

Method: Specific Conductance

Reference: "Methods for Chemical Analysis of Water and Wastes"  
EPA-600/4-79-020, revised March 1983, Method 120.1

Sensitivity: 0.1 mmhos/cm

Optimum Range: 0 - 100.0 mmhos/cm

Sample Handling: Determine on site

Reagents and Apparatus:

1. Conductivity meter - YSI Model 3560 Water Quality Monitoring System;
2. Conductivity Cell - YSI Model 3520 Flow-Through Conductivity Cell (K=5/cm);
3. Thermilinear Thermister - YSI Model 3510 Temperature Probe;
4. Deionized water; and
5. Conductivity standard, 1.0 mmhos/cm @25°C - YSI Model 3167.

Notes:

The conductivity meter is factory calibrated. The calibration is checked using a solution of known conductance.

Calibration Check

Connect the 3520 cell and a 3510 Temperature Probe to the 3500, and remove them from the sample chamber. Set the conductivity function switch to 2 ATC. Rinse the inside and outside of the cell and the probe with about 1/3 the content of the 3167 bottle. Place both of the sensors into the remainder of the solution in the bottle and allow them to come to temperature equilibrium. Make sure that the 3250 body is immersed so that the liquid level is half way up the knurled portion of the cell. Read the displayed value and determine if the cell/instrument is within specified accuracy. The displayed value is corrected to 25°C automatically and should be  $1.000 \pm 0.070$  mmhos/cm. If the value is not within specification replace 3250 cell.

## SOIL VOC SCREENING

Scope and Application: This method is applicable to screening VOCs in the headspace of soil samples.

Method: Photoionization

Sensitivity: Approximately 0.5 ppm depending on background

Optimum Range: Background to 2,000 ppm

Sample Handling: Determined on site

Reagents and Apparatus:

1. Mini Rae Classic Photoionization Detector (PID);
2. Calibration gas (commercially available standard cylinders containing isobutylene);
3. Calibration apparatus and tubing; and
4. Battery chargers.

Procedure:

1. Calibrate meter using the instrument manufacturer's calibration procedure attached.
2. The samples for VOC headspace screening will be prepared in the field by filling a 2- or 4-ounce soil jar to one-half its volume and sealing with a teflon-lined closure. Alternately, a polyethylene bag with zipper-type closure (e.g., Ziploc brand) may be used. The remaining sample will be placed in the appropriate jars for the analyses required.
3. Allow the sample for VOC headspace screening to remain at ambient temperature for a minimum of 10 minutes. This will allow for VOCs in the soil to reach equilibrium in the headspace of the container.
4. Remove the lid of the soil jar or open the bag slightly and insert the probe of the meter into the headspace.
5. Take the highest reading from the meter or readout of the instrument.
6. Record the reading in the field logbook.

## TOXIC VAPOR ANALYZER

Scope and Application: This method is applicable to screening methane and organic vapors in soil gas probes.

Method: Photoionization/Flame Ionization

Sensitivity:  $\pm 25$  percent of reading or  $\pm 2.5$  ppm, whichever is greater

Optimum Range: 0.5 to 500 ppm (photoionization)  
1.0 to 10,000 ppm (flameionization)

Sample Handling: Determine on site

Reagents and Apparatus:

1. Foxboro TVA - 1000B Toxic Vapor Analyzer;
2. Calibration gas (commercially available standard cylinders containing zero gas and 500 ppm methane gas);
3. Calibration apparatus and tubing; and
4. Battery charger.

Procedure:

1. Connect the sample probe (electrical and sample line connections) to the appropriate receptors on the TVA-1000B.
2. Calibrate analyzer using the instrument manufacturer's calibration procedure on page 19 in Attachment A.
3. Monitoring with the TVA-1000B will be performed while traversing grid lines spaced 30 meters apart as specified in the Section 5.0 of the Work Plan.
4. The vapor concentration may be read immediately on either two displays - one mounted directly on the hand-held sample probe and the other on the instrument side pack itself.
5. Both FID and PID readings will be displayed and logged simultaneously, the relative response of the two detectors may indicate the identity of the compound being measured. For example, the PID will not respond to methane, but the FID responds very well. Therefore, a high FID reading with virtually no PID response might indicate the presence of methane. Consequently, PIDs respond very well to some inorganic gases that FIDs cannot detect. Therefore, a high PID reading with no FID reading suggests the presence of an inorganic compound.

ATTACHMENT C

ASTM METHODS



Designation: D 422 – 63 (Reapproved 2002)

## Standard Test Method for Particle-Size Analysis of Soils<sup>1</sup>

This standard is issued under the fixed designation D 422; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Note 1 and Note 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-μm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 μm.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>2</sup>

E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>3</sup>

E 100 Specification for ASTM Hydrometers<sup>4</sup>

### 3. Apparatus

3.1 *Balances*—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved Nov. 10, 2002. Published March 2003. Originally published in 1935. Last previous edition approved in 1998 as D 422 – 63 (1998).

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 14.03.

3.2 *Stirring Apparatus*—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup<sup>5</sup> (Note 3) conforming to the general details shown in Fig. 3 (Note 4 and Note 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft<sup>3</sup>/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

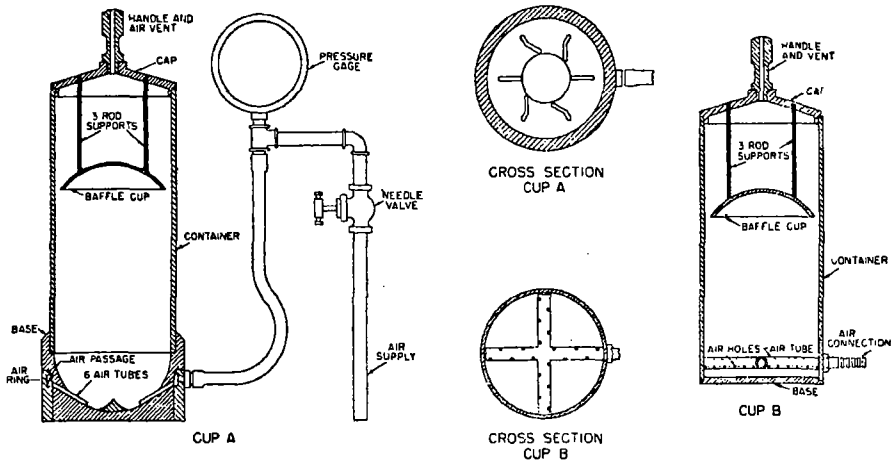
NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 *Hydrometer*—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

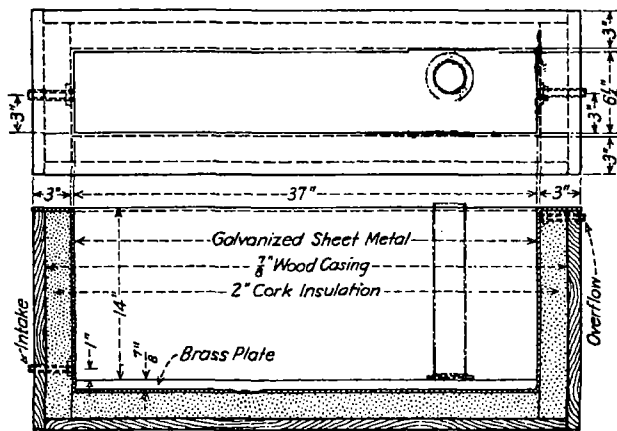
3.4 *Sedimentation Cylinder*—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and

<sup>5</sup> Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Order Adjunct No. ADJD0422.





**FIG. 3 Air-Jet Dispersion Cups of Apparatus B**



**FIG. 4 Insulated Water Bath**

in.	$\frac{7}{8}$	1	3	6 $\frac{1}{4}$	14	37
mm	22.2	25.4	76.2	158.2	356	940

**FIG. 4 Insulated Water Bath**

hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

## 5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
3/8 (9.5)	500
3/4 (19.0)	1000
1 (25.4)	2000
1 1/2 (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the

transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil-water slurry to the sedimentation cylinder.

## 10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil-water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

## 11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75- $\mu$ m) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

## CALCULATIONS AND REPORT

### 12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the  $\frac{3}{8}$ -in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the  $\frac{3}{8}$ -in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

### 13. Hygroscopic Moisture Correction Factor

13.1 The hygroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

### 14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight  $W$  in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\ 000/W) \times G/(G - G_1)](R - G_1) \quad (1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100 \quad (2)$$

where:

$a$  = correction fraction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

$P$  = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

$R$  = hydrometer reading with composite correction applied (Section 7),

**TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis**

Temperature, <sup>a</sup> C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

where:

$K$  = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of  $K$  for a range of temperatures and specific gravities are given in Table 3. The value of  $K$  does not change for a series of readings constituting a test, while values of  $L$  and  $T$  do vary.

15.3 Values of  $D$  may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of  $L$  is divided by  $T$  using the  $A$ - and  $B$ -scales, the square root being indicated on the  $D$ -scale. Without ascertaining the value of the square root it may be multiplied by  $K$ , using either the  $C$ - or  $CI$ -scale.

#### 16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

#### 17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an arithmetic scale as the ordinate. When the hydrometer analysis

is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

#### 18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

- |  |         |
|--|---------|
| (1) Gravel, passing 3-in. and retained on No. 4 sieve              | ..... % |
| (2) Sand, passing No. 4 sieve and retained on No. 200 sieve        | ..... % |
| (a) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve  | ..... % |
| (b) Medium sand, passing No. 10 sieve and retained on No. 40 sieve | ..... % |
| (c) Fine sand, passing No. 40 sieve and retained on No. 200 sieve  | ..... % |
| (3) Silt size, 0.074 to 0.005 mm                                   | ..... % |
| (4) Clay size, smaller than 0.005 mm                               | ..... % |
| Colloids, smaller than 0.001 mm                                    | ..... % |

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains



## Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils<sup>1</sup>

This standard is issued under the fixed designation D 2974; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 These test methods cover the measurement of moisture content, ash content, and organic matter in peats and other organic soils, such as organic clays, silts, and mucks.

1.2 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 653 Terminology Relating to Rock, Soil, and Contained Fluids<sup>2</sup>

D 3740 Practice for the Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction<sup>2</sup>

D 4753 Standard Specifications for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing<sup>2</sup>

E 145 Specification for Gravity Convection and Forced Ventilation Ovens<sup>3</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 For common definitions of terms in this standard, refer to Terminology D 653.

### 4. Summary of Test Methods

4.1 *Test Method A*—Moisture is determined by drying a peat or organic soil sample at 105°C. The moisture content is expressed either as a percent of the oven dry mass or of the as-received mass.

4.2 *Test Method B*—This is an alternative moisture method

which removes the total moisture in two steps: (1) evaporation of moisture in air at room temperature (air-drying), and (2) the subsequent oven drying of the air-dried sample at 105°C. This method provides a more stable sample, the air-dried sample, when tests for nitrogen, pH, cation exchange, and the like are to be made.

4.3 *Test Methods C and D*—Ash content of a peat or organic soil sample is determined by igniting the oven-dried sample from the moisture content determination in a muffle furnace at 440°C (Method C) or 750°C (Method D). The substance remaining after ignition is the ash. The ash content is expressed as a percentage of the mass of the oven-dried sample.

4.4 Organic matter is determined by subtracting percent ash content from one hundred.

### 5. Significance and Use

5.1 This test method can be used to determine the moisture content, ash content, and percent organic matter in soil.

5.2 The percent organic matter is important in classifying a peat or other organic soil.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

### 6. Apparatus

6.1 *Oven*, meeting the requirements of E 145 and capable of being regulated to a constant temperature of  $105 \pm 5^\circ\text{C}$ .

NOTE 2—The temperature of 105°C is quite critical for organic soils. The oven should be checked for "hot spots" to avoid possible ignition of the specimen.

6.2 *Muffle Furnace*, capable of producing constant temperatures of 440°C and 750°C.

6.3 *Balance or Scale*, a balance or scale for determining the mass of the soil having a minimum capacity of 500 g and meeting the requirements of Standard D 4753 for a balance or scale of 0.01 g readability.

6.4 *Rubber Sheet, Oil Cloth*, or other non-absorbent material.

6.5 *Evaporating Dishes*, of high silica or porcelain of not

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.22 on Soil as a Medium for Plant Growth.

Current edition approved August 10, 2000. Published November 2000. Originally published as D 2974 – 71. Last previous edition D 2974 – 87 (1995).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.08.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.06.

750°C and hold until the specimen is completely ashed (no change of mass occurs after a further period of heating).

8.2.2.4 Cover with the retained aluminum foil cover, cool in a desiccator, and determine the mass to the nearest 0.01 g.

8.2.2.5 This test method should be used when peats are being evaluated for use as a fuel.

#### 8.2.3 Calculation for Test Methods C and D

8.2.3.1 Calculate the ash content as follows:

$$\text{Ash Content, \%} = (C \times 100) / B \quad (6)$$

where:

C = ash, g, and

B = oven-dried test specimen, g.

#### 8.3 Organic Matter Determination

##### 8.3.1 Calculation

8.3.1.1 Determine the amount of organic matter by difference, as follows:

$$\text{Organic matter, \%} = 100.0 - D \quad (7)$$

where:

D = ash content, %.

## 9. Report

9.1 Report the following information:

9.1.1 Results for organic matter and ash content, to the nearest 0.1 %.

9.1.2 Furnace temperature used for ash content determinations.

9.1.3 Whether moisture contents are by proportion of as-received mass or oven-dried mass.

9.1.3.1 Express results for moisture content as a percentage of as-received mass to the nearest 0.1 %.

9.1.3.2 Express results for moisture content as a percentage of oven-dried mass as follows:

(a) Below 100 % to the nearest 1 %.

(b) Between 100 % and 500 % to the nearest 5 %.

(c) Between 500 % and 1000 % to the nearest 10 %.

(d) Above 1000 % to the nearest 20 %.

## 10. Precision and Bias

10.1 *Precision*—Test data on precision is not presented due to the nature of the soil materials tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program.

10.1.1 The Subcommittee D 18.06 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

10.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

## 11. Keywords

11.1 ash content; moisture content; organic soil; peat; % organic matter

## SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (95) that may impact the use of the standard.

(1) Section 1.2—Added second sentence to update SI statement.

(2) Inserted new Section 2 on Referenced Documents and new Section 3 on Terminology. Renumbered subsequent sections as needed.

(3) Inserted new Section 5 on Significance and Use and renumbered subsequent sections as needed.

(4) Renumbered Section 5—Inserted standard Note 1 referencing D 3740 and renumbered following notes as needed.

(5) Inserted new footnotes 2 and 3 for referenced ASTM documents.

(6) Section 6.1—Inserted reference to E 145.

(7) Section 6 Apparatus—Inserted a balance or scale as 6.3 and a rubber sheet, etc. as 6.4.

(8) Changed heading of Section 7 from Preparation of Sample

to Sampling and Test Specimens.

(9) Renumbered section 7.1—Clarified procedures for mixing, subsampling and storing material.

(10) Added Section 8 Procedure and renumbered sections on moisture content, ash content and organic matter to fall under procedure.

(11) Renumbered sections 8.1.1.2 and 8.1.3.2—Deleted “Mix the sample thoroughly and” with “Following the instructions in section 4.1 above.”

(12) Renumbered sections 8.1.1.4, 8.1.3.2, 8.2.1.1, 8.2.1.4, 8.2.2.1, and 8.2.2.3—specified determining the mass to the nearest 0.01 g.

(13) Renumbered section 8.1.3.2—Changed “sample” to “test specimen.”

(14) Updated Precision and Bias statement.

(15) Added Keywords section.

(16) Added Summary of Changes section.



## Standard Test Method for pH of Soils<sup>1</sup>

This standard is issued under the fixed designation D 4972; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

### 1. Scope \*

1.1 This test method covers the measurement of the pH of soils for uses other than for corrosion testing. Such measurements are used in the agricultural, environmental, and natural resources fields. This measurement determines the degree of acidity or alkalinity in soil materials suspended in water and a 0.01 M calcium chloride solution. Measurements in both liquids are necessary to fully define the soil's pH. This variable is useful in determining the solubility of soil minerals and the mobility of ions in the soil and assessing the viability of the soil-plant environment. A more detailed discussion of the usefulness of this parameter is not warranted here; however, it can be found in many discussions of the subject. A few such discussions are given as Refs (1-6)<sup>2</sup> at the end of the text.

1.2 The values given in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials<sup>3</sup>

D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>4</sup>

D 1193 Specification for Reagent Water<sup>5</sup>

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction<sup>6</sup>

G 51 Test Method for pH of Soil for Use in Corrosion Testing<sup>7</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.22 on Soil as a Medium for Plant Growth.

Current edition approved Jan. 10, 2001. Published February 2001. Originally published as D 4972 – 89. Last previous edition D 4972 – 95a.

<sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of the test method.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.09.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 04.08.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 03.02.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 For common definitions of terms used in this standard, refer to Terminology D 653.

### 4. Summary of Test Method

4.1 Measurement of the pH of soils in both suspensions of water and a calcium chloride solution are made with either a potentiometer using a pH sensitive electrode system (Method A), or pH sensitive paper (Method B). The potentiometer is calibrated with buffer solutions of known pH. The pH sensitive paper is a less accurate measurement and should only be used for a rough estimate of the soil pH. The electrode must be used for this measurement unless the pH sensitive paper is specified.

### 5. Significance and Use

5.1 The pH of the soil is a useful variable in determining the solubility of soil minerals and the mobility of ions in the soil and assessing the viability of the soil-plant environment.

5.2 pH measurements are made in both water and a calcium chloride solution because the calcium displaces some of the exchangeable aluminum. The low ionic strength counters the dilution effect on the exchange equilibrium by setting the salt concentration of the solution closer to that expected in the soil solution. The pH values obtained in the solution of calcium chloride are slightly lower than those measured in water due to the release of more aluminum ions which then hydrolyses. Therefore, both measurements are required to fully define the character of the soil's pH.

5.3 For the purpose of this test method the test soil must be sieved through a No. 10 sieve (2 mm sieve mesh openings). Measurements on soils or soil fractions having particle sizes larger than 2 mm by this test method may be invalid. If soil or soil fractions with particles larger than 2 mm are used, it must be stated in the report since the results may be significantly different.

5.4 All water used for this test method must be ASTM Type III or better. Type III water is defined by Specification D 1193. It is prepared by distillation, ion exchange, reverse osmosis, or a combination thereof.

### 6. Interferences

6.1 This test method as measured by a pH probe has possible interferences due to a suspension effect or sedimentation potential. Users interested in a detailed discussion of the

\*A Summary of Changes section appears at the end of this standard.

Therefore, results of two properly conducted tests in the same or different laboratories should not differ by more than 0.53<sup>9</sup> (pH units) for the water mixture and 0.60 pH units for the calcium chloride mixture.

12.1.1.1 The precision of Method A presented was determined by the National Technical Center of the United States Department of Agriculture. In their evaluation they used 174 replicates for the water mixture and 32 replicates in testing the calcium chloride mixture.

12.1.1.2 The precision of Method B presented was determined by the United States Army Environmental Hygiene Agency. In their evaluation they used 25 replicates in testing each mixture.

12.1.2 *Between-Laboratory Precision*—The between-laboratory standard deviation has not been determined for either method. Subcommittee D18.22 is actively seeking data to evaluate the between laboratory precision of this test method.

12.2 *Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

### 13. Keywords

13.1 acidity; alkalinity; pH; reaction; soil

## REFERENCES

- (1) Garrels, R. M., and Christ, C. L., *Solutions, Minerals, and Equilibria*, Freeman Cooper, San Francisco, CA, 1965.
- (2) Greenland, D. J., and Hayes, M. H. B., *The Chemistry of Soil Processes*, Wiley, New York, NY, 1981.
- (3) Sposito, G., *The Thermodynamics of Soil Solutions*, Clarendon, Oxford, United Kingdom, 1981.
- (4) Davies, J. T., and Rideal, E. K., *Interfacial Phenomena*, Academic, New York, NY, 1963.
- (5) Hunter, R. J., *Zeta Potential in Colloid Science*, Academic, New York, NY, 1981.
- (6) Perrin, D. D., and Dempsey, B., *Buffers for pH and Metal Ion Control*, Chapman and Hall, London, United Kingdom, 1974.

## SUMMARY OF CHANGES

This section identifies location of changes to this practice since the last edition.

- (1) Added Practice D 3740 and Terminology D 653 to Referenced Documents.
- (2) Added Section 3 on Terminology.

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).*



Designation: D 6724 – 04

## Standard Guide for Installation of Direct Push Ground Water Monitoring Wells<sup>1</sup>

This standard is issued under the fixed designation D 6724; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide describes various direct push ground water monitoring wells and provides guidance on their selection and installation for obtaining representative ground water samples and monitoring water table elevations. Direct push wells are used extensively for monitoring ground water quality in unconsolidated formations. This guide also includes discussion of some groundwater sampling devices which can be permanently emplaced as monitoring wells.

1.2 This guide does not address the single event sampling of ground water using direct push water samplers as presented in Guide D 6001. The methods in this guide are often used with other tests such as direct push soil sampling (Guide D 6282) and the cone penetrometer test (Guide D 6067). The present guide does not address the installation of monitoring wells by rotary drilling methods such as those presented in Practice D 5092. Techniques for obtaining ground water samples from monitoring wells are covered in Guide D 4448.

1.3 The installation of direct push ground water monitoring wells is limited to unconsolidated soils and sediments including clays, silts, sands, and some gravels and cobbles. Penetration may be limited, or damage may occur to equipment, in certain subsurface conditions; some of which are discussed in 5.5. Information in this guide is limited to ground water monitoring in the saturated zone.

1.4 This guide does not purport to comprehensively address all of the methods and issues associated with monitoring well installation. Users should seek input from qualified professionals for the selection of proper equipment and methods that would be the most successful for their site conditions. Other methods may be available for monitoring well installation, and qualified professionals should have flexibility to exercise judgement concerning alternatives not covered in this guide. The practice described in this guide is current at the time of issue; however, new, alternative, and innovative methods may become available prior to revisions. Therefore, users should consult with manufacturers or producers prior to specifying program requirements.

1.5 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgement. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

- D 653 Terminology Relating to Soil, Rock, and Contained Fluids
- D 4448 Guide for Sampling Ground Water Monitoring Wells
- D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
- D 5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites
- D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers
- D 5254 Practice for Minimum Set of Data Elements
- D 5299 Guide for Decommissioning Monitoring Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
- D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
- D 5474 Guide for Selection of Data Elements for Ground Water Investigation

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water.

Current edition approved July 1, 2004. Published July 2004. Originally approved in 2001. Last previous edition approved in 2001 as D 6724-01.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.



that cross-contamination by “smearing” or “drag-down” (that is, driving shallow contamination to deeper levels) does not occur, and that hydraulic connections between otherwise isolated water bearing strata are not created. Similar precautions as those applied during conventional rotary drilling operations (Guide D 6286) should be followed.

5.7 There have been no conclusive comparisons of effectiveness of sealing between drilled monitoring wells and direct push monitoring wells. As with drilled monitoring wells, sealing methods must be carefully applied to be effective.

5.8 Selection of direct push monitoring wells versus conventional rotary drilled monitoring wells should be based on many issues. The advantages and disadvantages of the many available types of driving equipment and well systems must be considered with regard to the specific site conditions. Specific well systems and components, as well as direct push driving equipment, are described in Section 7.

#### 5.9 Advantages:

5.9.1 Minimally intrusive and less disturbance of the natural formation conditions than many conventional drilling techniques.

5.9.2 Rapid and economical.

5.9.3 Smaller equipment with easier access to many locations.

5.9.4 Use of shorter screens can eliminate connections between multiple aquifers providing better vertical definition of water quality than long well screens.

5.9.5 Generates little or potentially no contaminated drill cuttings.

5.9.6 Less labor intensive than most conventional drilling techniques.

#### 5.10 Disadvantages:

5.10.1 Cannot be used to install monitoring devices in consolidated bedrock and deposits containing significant cobbles and boulders.

5.10.2 Small diameter risers and screens limit the selection of useable down-hole equipment for purging and sampling.

5.10.3 Difficulty installing sand pack in small annular space if gravity installation of sand pack is used.

5.10.4 Difficulty installing grout in same annular space unless appropriately designed equipment is used.

### 6. Pre-Installation Considerations

6.1 *Site Characterization*—Successful installation of direct push ground water monitoring wells must be preceded by appropriate site characterization activities. These activities may include reconnaissance, research, conceptual model development, exploratory field investigations, and confirmation and re-evaluation of any existing flow models.

6.2 For the installation to be successful, it is imperative that the target aquifer be located accurately. As with any well installation, the geologic conditions must be understood and the stratigraphy must be known. Although direct push wells can monitor thinner aquifers, with more precision, they may be ineffective if incorrectly placed. In thicker aquifers, and when seeking dense non-aqueous phase liquids, screens may need to be located in the bottom of the water-bearing stratum. Wells placed without determination of nearby geologic conditions can be ineffective and possibly dangerous. Geologic investiga-

tions should look for perched aquifers and use installation methods which will avoid any crosscontamination of the unit.

6.3 Environmental site characterization approaches are described in Guide D 5730. Proper site characterization for monitoring well placement is reviewed in Practice D 5092 on Monitoring Well Design.

6.3.1 *Characterization Tools*—In geologic settings amenable to the use of direct push ground water monitoring wells, other direct push methods and tools can likely also be used to effectively characterize the site. For example, the Cone Penetrometer Test (CPT) (Guide D 6067) is an effective tool for mapping stratigraphy and locating target layers. Other sensors, such as electrical conductivity and optical detectors have been placed on CPT and other direct push systems. Direct push soil sampling (Guide D 6282) and water sampling (Guide D 6001) can be used in advance to locate strata of concern. Direct push characterization experience at a site can guide the user in well design or device selection.

6.3.2 *Sampling During Installation*—Many direct push systems can take soil or water samples as part of the well installation process. For example, two-tube systems described in direct push soil sampling Guide D 6282 can be used to collect soil samples while driving. When the target aquifer is reached, the well screen system can be installed in the casing. Sampling data taken prior to well installation can confirm the target stratum has been reached.

6.3.3 *Sampling Systems*—There is a wide variety of direct push ground water sampling systems which can also be used for ground water monitoring. Direct push water sampling Guide D 6001 describes exposed screen versus protected screen samplers. Guide D 6282 describes the differences in two-tube and single-rod direct push soil sampling systems.

6.4 *Access and Clearances*—The selection of driving equipment should consider the accessibility of the installation site. The site should be surveyed for accessibility. Utility clearances may be required. Certain driving methods are incompatible with nearby hazards (for example, flammables). Also check for overhead utility lines during the site survey.

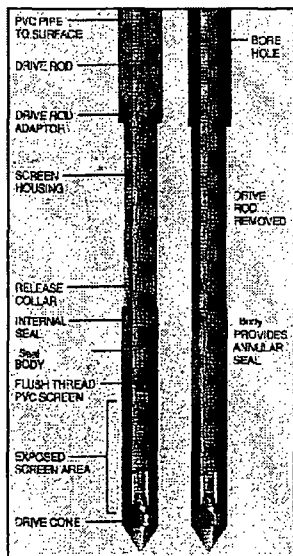
6.5 *Well Size Selection*—Driving resistance can govern the selection of an appropriate well diameter. Driving resistance can be evaluated by direct push testing on the site prior to well installation. Larger diameter monitoring wells may be easy to install on soft or loose ground sites. Smaller diameter monitoring wells may facilitate deeper installation on sites that are more resistant to penetration, but also present additional considerations for use as discussed below.

6.5.1 The availability of appropriate well development and sampling equipment for use in small-diameter monitoring wells may be limited. Many conventional down-hole pumps for purging and sampling are too large for use in small-diameter screens and risers.

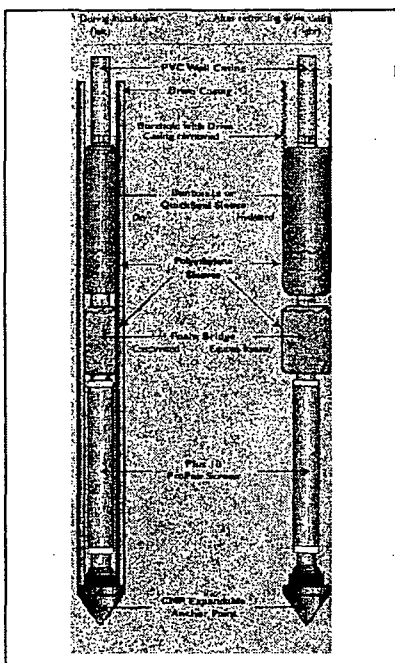
6.5.2 Small diameter monitoring wells, because they are generally less rigid than larger diameter monitoring wells, require special attention during backfilling to maintain vertical alignment. This may include the use of centralizers.

### 7. Direct Push Wells Systems and Components

7.1 *Drive Rod and Casing*—In some instances the well itself may serve as the drive rod. Otherwise, it either surrounds



**FIG. 2 Example of a Steel Seal Body Above the Screen**



**FIG. 3 Direct Push Well with Modular Sealing Components**

and bentonite sleeves used above the screened interval. Rubber wiper seal may also be used. Whether this barrier is formed by the addition of fine to medium sand, by collapse of the surrounding formation, or mechanically, the materials employed must be chosen to be compatible with the local groundwater conditions and contaminants of interest.

**7.5 Modular Well Systems**—The most recent developments have been towards the use of modular components for placing sand pack and seals. Pre-packed screens can be used with most drive systems. The screens are stainless steel wire mesh filled with sand of different gradations. Fig. 3 shows the use of these modular sand packs.

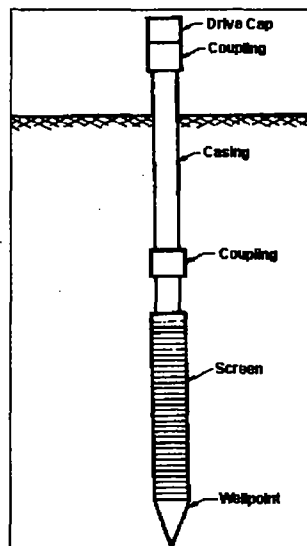
**7.6 Other Variations**—Numerous innovations have been developed for ground water monitoring through direct push well systems. For example, multiple screened sections can be completed in one installation, and sampling of multiple zones can be performed by using packers or sampling ports for ground water extraction. Another recent development has been the use of everting flexible sock system liners to seal the borehole and isolate a water sampling interval (21).

## 8. Installation Techniques

8.1 There are several techniques for installing direct push monitoring wells. Techniques can be broadly classified into two categories: exposed screen techniques, and protected screen techniques. Each of the systems described hereafter may require a unique installation procedure. Regardless of the choice of techniques and systems, a written operating procedure should be developed which allows some flexibility in response to field conditions. Project sampling plans and standard operating procedures should be consulted prior to installation.

**8.2 Direct Push Driving Equipment**—Direct push Guides D 6001 and D 6282 describe typical driving systems. Some systems are manual (slam bar, hand held electric or pneumatic hammers), static weight (cone penetrometers), percussion (hydraulic hammers, air hammers, electric hammers), and vibratory systems. In some cases, direct push monitoring wells may be installed in combination with rotary drilling.

**8.3 Exposed Screen Techniques**—One method of installing direct push wells is to advance a screen and riser of constant diameter that remain in direct contact with the formation during installation. The riser may be driven either alone or by using a mandrel rod inside the screen and riser (Fig. 4). Because the well screen is exposed to soil during driving, development by surging or jetting will be necessary to remove sediment from the screen slots (see Guide D 5521 for well development methods). When installing exposed screen monitoring wells the slotted screens may become clogged with fine-grained materials if any are present in the penetrated



**FIG. 4 Example of an Exposed-Screen Driven Well Point (11)**

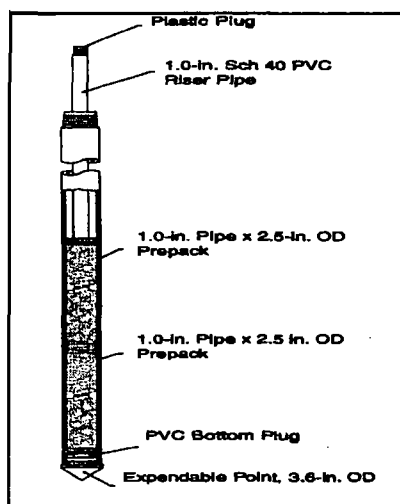


FIG. 7 Example of Prepacked Screens Installed After the Drive Casing is in Position (20)

be lowered down into the casing following driving and prior to casing withdrawal, or the bottom end may be attached to an expendable push point, which remains in the ground upon retraction of the drive rods and acts as an anchor. The casing provides a positive temporary seal and allows for control of sand pack and permanent seal placement as it is retracted. Two-tube systems also allow for soil or ground water sampling along the way. However, they must be checked for standing water in the outer tube which, if not drained, may impact sample quality. Typical well diameters are from one-half to two inches.

**8.4.3 Filter Packs and Seals**—In a surficial aquifer it may be appropriate to allow the formation to collapse back in against the screen and riser without adding a sand pack. In this case the surface completion method must provide adequate protection against infiltration by surface runoff. Otherwise, sand pack and seals, if not provided by pre-packed or modular construction (7.3.2 and 7.5, respectively), can be placed by tremie or pouring methods, or by pumping.

## 9. Installation Procedure

**9.1 Decontamination of Materials**—Well components and installation equipment may require decontamination before and/or after well installation. Consult Practice D 5088 for decontamination procedures. If the well is to be used for water chemistry testing, at least one rinsewater sample of the well material will be required following decontamination and prior to installation.

**9.2 Installation**—Drive the direct push monitoring well in accordance with the standard operating procedures developed for the push system and/or monitoring well (8.1). Record all assembly lengths and rod or casing lengths, and any unusual driving conditions as the push progresses on the well completion log (Fig. 8). Record water levels if required (see Test Method D 4750). For cased systems in sand below the water table, it may be necessary to fill the casing with clean water to prevent sand heaving. With cased systems, it may be necessary to check for ground water infiltration using a water level meter

CPT WELL INSTALLATION REPORT	
Project: _____	Observation Well: _____
City/State: _____	CPT ID: _____
Client: _____	Installation Date: _____
Crew Chief: _____	Location: _____
File No.: _____	
Ground El. _____	
E. Datum _____	
Comments: _____	
	Type of Protective Cover/Lock _____ Depth of Top of Roadway Box below Ground Surface _____ Depth of Top of Riser Pipe below Ground Surface _____ Type of Protective Casing _____ Length _____ Inside Diameter _____ Depth of Bottom of Roadway Box _____ Seal: _____ Type _____ Depth to Top (ft) _____ Thickness (in) _____ Type of Riser Pipe _____ Inside Diameter of Riser Pipe _____ Type of Backfill around Riser _____ Diameter of Largest CPT Expander _____ Depth of Top of Wellpoint _____ Type of Poles or Manufacturer: _____ Screen Gauge or Size of Openings _____ Diameter of Wellpoint _____ Depth of Bottom of Wellpoint _____ B6 Trap _____ Depth of Bottom of Borehole _____ (Depths refer to ground surface)
Riser length (L1) + Screen length (L2) + Length of all trap (L3) = Total length	

FIG. 8 Example of a Direct Push Well Completion Report

prior to detaching the expendable tip. This check is imperative in conditions of contaminated perched water.

**9.3 Centralizers**—For small diameter casings (less than half the size of the borehole created), the use of centralizers prevents deflections of the riser during backfilling of the annular space. Riser deflection can later interfere with the free passage of bailers and other equipment through the casing. Centralizers may also assist in sealing procedures by keeping the riser in a consistent position within the borehole.

**9.4 Sealing**—Procedures for sealing direct push monitoring wells are similar to those in Practice D 5092. Direct push sealing considerations and procedures are also addressed in sampling Guides D 6001 and D 6282. Groundwater that has entered the cased system may cause difficulty in placing seal materials by the gravity-pouring method. New grouting equipment allows for efficient and effective installation of well seals and grout (20 to 30 % solids bentonite) by bottom-up tremie methods with tremie tubes as small as 0.25-in. inside diameter. Depth to the top of seal materials can be periodically checked using rods or weighted tape lowered into the annular space.

**9.5 Surface Completion**—Well capping details vary from simple to detailed, similar to rotary drilled monitoring wells. After the final height of the riser is established, record the elevation of the top of the riser pipe.

**9.6 Well Development**—Direct-push monitoring wells can be developed using mechanical surging, pumping and backwashing, hydraulic jetting, or inertial lift pumps. The first three methods are described in detail in Guide D 5521. Inertial-lift

## 11. Keywords

11.1 direct push; ground water; monitoring well; site investigation

## REFERENCES

- (1) Foster, M., Stefanov, J., Bauder, T., Shinn, J., and Wilson, R., (1995), *Ground Water Monitoring Review*, National Ground Water Association, Dublin, OH.
- (2) Thornton, D., Ita, S., and Larsen, K., 1997, Broader Use of Innovative Ground Water Access Technologies. In Superfund XVIII Conference Proceedings, Vol 2. p. 639 - 646. E.J. Krause and Assoc. Washington, D.C.
- (3) McCall, W., Stover, S., Enos, C., and Fuhrmann, G., 1997, Field Comparison of Direct Push Prepacked Screen Monitoring Wells to Paired HSA 2" PVC Wells. In Superfund XVIII Conference Proceedings, Vol 2. p. 647 - 655. E.J. Krause and Assoc. Washington, D.C.
- (4) McCall, W., 1999, "Field Comparison of Paired direct push and HSA Monitoring Wells," Natural Attenuation of Chlorinated Solvents, Petroleum Hydrocarbons, and Other Organic Compounds," April 19-22, 1999, Alleman and Leeson, eds., Battelle Press, Columbus, OH and Richland WA.
- (5) Kram, Mark, D. Lorenzana, J. Michaelson, E. Lory, 2001. Performance Comparison: DirectPush Wells Versus Drilled Wells, Naval Facilities Engineering Service Center Technical Report, TR-2120-ENV, January 2001, 55 pp.
- (6) Parker, L.V. 1992. Suggested Guidelines for the Use of PTFE, PVC and Stainless Steel in Samplers and Well Casings. In Current Practices in Ground Water and Vadose Zone Investigations, ASTM STP 1118, David M. Nielsen and Martin N. Sara, editors, American Society for Testing and Materials, Philadelphia, pp. 217-229.
- (7) Parker, L.V. and T.A. Ranney. 1994. Softening of Rigid PVC by Aqueous Solutions of Organic Solvents. CRREL Special Report 94-27.
- (8) Parker, L.V. and T.A. Ranney. 1995. Additional Studies on the Softening of Rigid PVC by Aqueous Solutions of Organic Solvents. CRREL Special Report 95-8.
- (9) Parker, L.V. and T.A. Ranney. 1996. Further Studies on the Softening of Rigid PVC by Aqueous Solutions of Organic Solvents, CRREL Special Report 96-26.
- (10) Ranney, T.A. and L.V. Parker. 1997. Comparison of Fiberglass and Other Polymeric Well Casings: Part I. Susceptibility to Degradation by Chemicals. *Ground Water Monitoring and Remediation*, vol. 16, no.2: 97-103.
- (11) Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielsen, and J.E. Denne. 1989. Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells, National Water Well Association, Dublin, OH.
- (12) D. Driscoll, Fletcher G. 1986. *Groundwater and Wells*, Second Edition. Johnson Screens, St. Paul, MN.
- (13) Barcelona, M.J., J.P. Gibb, R.A. Miller. 1984. A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling. US Environmental Protection Agency Report Number EPA-600/2-84-024, Robert S. Kerr Environmental Research Laboratory, US EPA, Ada, OK.
- (14) Parker, L.V., A.D. Hewitt, and T.F. Jenkins. 1990. "Influence of Casing Materials on Trace Level Chemicals in Well Water," *Ground Water Monitoring and Remediation* 10(2):146-156.
- (15) Hewitt, A.D. 1992, "Potential of Common Well Casing Materials to Influence Aqueous Metal Concentrations," *Ground Water Monitoring and Remediation* 12(2):131-136.
- (16) Hewitt, A.D. 1994 "Dynamic Study of Common Well Screen Materials," *Ground Water Monitoring and Remediation* 14(1):87-94.
- (17) Oakley, D. and N.E. Korte. 1996. Nickel and Chromium in Ground Water Samples as Influenced by Well Construction and Sampling Methods, *Ground Water Monitoring and Remediation* 16(1): 93-99.
- (18) EPA 1986, Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1, PB87-107751. September.
- (19) EPA 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance. Office of Solid Waste. EPA/530-R-93-001, PB93-139 350. November.
- (20) Geoprobe Systems, (1999), "Geoprobe Prepack Screen Monitoring Well-Standard Operating Procedure," Technical Bulletins 99-2000 and - 2500, Geoprobe Systems, Salina, Kansas.
- (21) Keller, C., (1999), "Brief Summary of the FLUTE Water Sampling Systems and Installation Procedures," Flexible Liner Underground Technologies LTD, 6 Easy St., Santa Fe, NM.
- (22) Applied Research Associates, (1998), "Work Plan for direct push Monitoring Point Assessment," Contract No. F08037-98-C6002 task 32.03S, Air Force Research Laboratory, Air Base and Environmental Technology Division, Tyndall Air Force Base, August 31
- (23) Cordry, K.E., 1995. "The Powerpunch," In *Proceedings of the 9th National Outdoor Action Conference*, National Ground Water Association, Columbus, OH.
- (24) Puls, Robert W., and Michael J. Barcelona, 1996. EPA Ground Water Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. EPA/540/S-95/504. April.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).



## Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope \*

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

Note 1—Practice D 6066 can be used when testing loose sands below the water table for liquefaction studies or when a higher level of care is required when drilling these soils. This practice provides information on drilling methods, equipment variables, energy corrections, and blow-count normalization.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>2</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>
- D 4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems<sup>2</sup>
- D 6066 Practice for Determining the Normalized Penetration Resistance Testing of Sands for Evaluation of Liquefaction Potential<sup>3</sup>

### 3. Terminology

#### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *anvil*—that portion of the drive-weight assembly

which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the  $140 \pm 2$  lb ( $63.5 \pm 1$  kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9  $\Delta N$ —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by  $360^\circ$  (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for standard penetration test, a term by which engineers commonly refer to this method.

### 4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

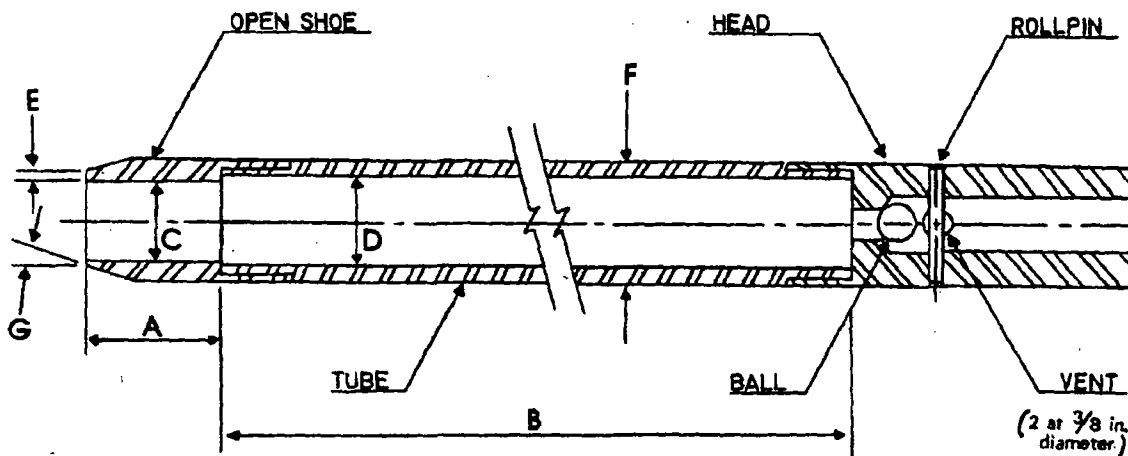
4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and

<sup>1</sup> This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

Current edition approved Jan. 10, 1999. Published March 1999. Originally published as D 1586 – 58 T. Last previous edition D 1586 – 98.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.09.



- A = 1.0 to 2.0 in. (25 to 50 mm)  
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)  
 C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)  
 D = 1.50 ± 0.05 - 0.00 in. (38.1 ± 1.3 - 0.0 mm)  
 E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)  
 F = 2.00 ± 0.05 - 0.00 in. (50.8 ± 1.3 - 0.0 mm)  
 G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 4—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

## 6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

## 7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling

observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.5 The variability in *N*-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting *N* on the basis of comparative energies. A method for energy measurement and *N*-value adjustment is given in Test Method D 4633.

## 10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

## SUMMARY OF CHANGES

(1) Added note to Section 1, Scope. The note refers to a related standard, Practice D 6066.

(2) Added Practice D 6066 to Section 2 on Referenced Documents.

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.*



## Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>1</sup>

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

### 1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

**NOTE 1**—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.5 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>

D 1452 Practice for Soil Investigation and Sampling by Auger Borings<sup>2</sup>

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Sept. 15, 1993. Published November 1993. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 90.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>

D 2113 Practice for Diamond Core Drilling for Site Investigation<sup>2</sup>

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>2</sup>

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)<sup>2</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

**NOTE 2**—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

**Cobbles**—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

**Boulders**—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 **clay**—soil passing a No. 200 (75- $\mu$ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 **gravel**—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

**coarse**—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

**fine**—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

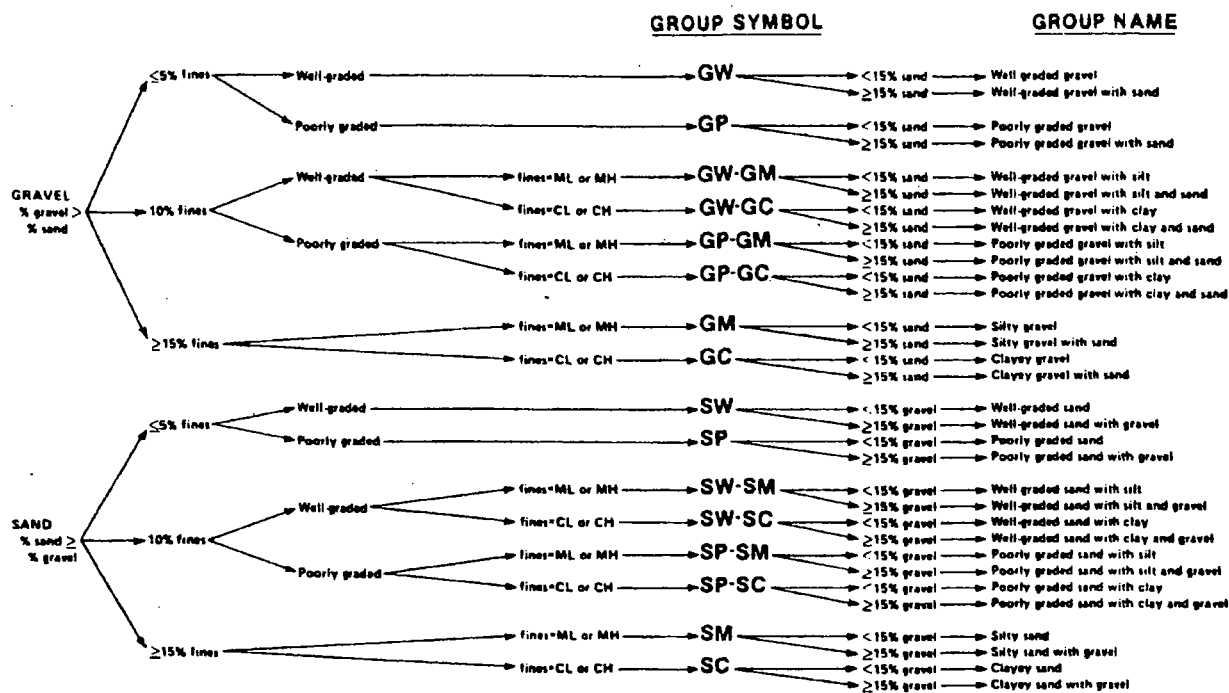
3.1.1.4 **organic clay**—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 **organic silt**—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 **peat**—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 **sand**—particles of rock that will pass a No. 4





NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

**Borderline Symbol**—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

## 5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

## 6. Apparatus

### 6.1 Required Apparatus:

6.1.1 Pocket Knife or Small Spatula.

### 6.2 Useful Auxiliary Apparatus:

6.2.1 Small Test Tube and Stopper (or jar with a lid).

6.2.2 Small Hand Lens

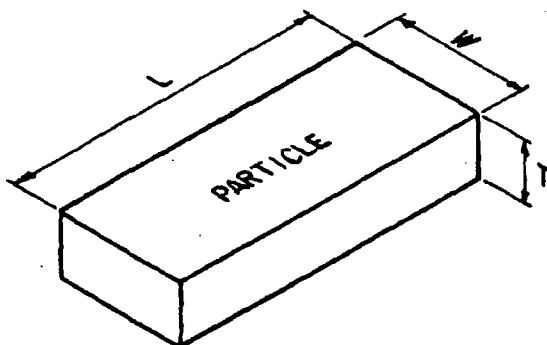
## 7. Reagents

7.1 Purity of Water—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 Hydrochloric Acid—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

## PARTICLE SHAPE

W=WIDTH  
T=THICKNESS  
L=LENGTH



FLAT:  $W/T > 3$   
ELONGATED:  $L/W > 3$   
FLAT AND ELONGATED:  
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (8 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation.

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.  
10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

#### 11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

#### 12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

#### 13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

#### 14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

##### 14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

##### 14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

## 16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
  - Gravel—fine, coarse
  - Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
- For intact samples:
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

## 17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

## 18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay  
ML/CL clayey silt  
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

#### X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

#### X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

<i>Prefix:</i>	<i>Suffix:</i>
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

<i>Group Symbol and Full Name</i>	<i>Abbreviated</i>
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)sbc
ML, gravelly silt with sand and cobbles	g(ML)c